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CARCASS TRAITS, MEAT QUALITY, GROWTH CURVES AND NUTRITIONAL NEEDS ESTIMATED BY INRAPORC® OF MOURA CROSSBREED PIGS

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Thesis presented as Partial fulfillment for the Degree of. Doctor in Veterinary Sciences at Post Graduation program in Veterinary Sciences, Federal University of Paraná, Brazil.

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RESUMO EXPANDIDO

A raça de suínos Moura é localmente adaptada no Brasil e é possivelmente derivada das raças Ibéricas, sendo amplamente disseminada na região Sul do Brasil até o início das primeiras décadas do século 20. Essa raça é caracterizada por alta rusticidade e capacidade de produção de gordura intramuscular e subcutânea, motivo pelo qual a gordura derivada desses animais era utilizada como fonte de energia e para a preservação de alimentos. A partir da década de 1970 ocorreu a popularização do óleo vegetal e a produção de suínos passou a objetivar carne, ocasionando a substituição de raças nacionais por raças estrangeiras especializadas na produção de carne magra. Desde então, os estudos sobre suínos realizados no Brasil passaram a objetivar as características produtivas das raças estrangeiras recém introduzidas e poucas informações foram produzidas sobre raças nacionais

Com a realização do presente estudo, o objetivo dos autores foi estudar o desempenho zootécnico, qualidade de carcaça e carne, cortes, curvas de crescimento e estabelecer as necessidades nutricionais pelo software INRAPORC® em suínos 29,7% Duroc, 15,6% Pietrain, 17,2% Large White, 25% Landrace e 12,5% Moura. Essa genética é resultado de projeto da EMBRAPA Suínos e Aves com o objetivo de melhorar a qualidade de carne de suínos com a introdução da raça Moura. Os suínos foram mantidos em baias separadas por sexo, com 4 a 5 animais por baia e alimentação à vontade. As dietas foram formuladas de forma a suprir ou exceder as necessidades estimadas pelo NRC (NRC, 2012) e foram divididas em quatro fases, de acordo com o peso vivo: 22 a 60 kg, 60 a 80 kg, 80 a 115 kg e 115 a 130 kg. O desempenho zootécnico, qualidade de carcaça e qualidade de carne foram avaliados em 131 suínos abatidos com 100, 115 e 130 kg de peso vivo. Para a avaliação dos cortes, utilizou-se 24 suínos: 4 machos e 4 fêmeas para cada peso de abate (PA): 100, 115 e 130 kg. As curvas de crescimento foram avaliadas pela dissecação em carne, ossos, pele e gordura de 56 suínos (28 machos e 28 fêmeas) abatidos com 22, 35, 60, 80, 100, 115 e 130 kg.

A genética avaliada demonstrou altos níveis de extrato etéreo, espessura de toucinho (aferida por ultrassonografia um dia antes do abate e na carcaça) e área de gordura, que aumentaram linearmente conforme aumento no PA ($P<0,01$) e foram superiores nos machos ($P<0,01$). Quando aferida na altura da última costela, o crescimento da espessura de toucinho nos machos e fêmeas foi de 0,220 mm/kg PA aumentado na carcaça e 0,180 mm/kg PA aumentado por ultrassonografia. A média da espessura de toucinho de machos e fêmeas aos 130 kg foi de 28,41 mm e a média de gordura intramuscular foi de 2,61%. Esses valores demonstram a capacidade das raças Moura e Duroc em depositar gordura subcutânea, embora em pequena proporção no cruzamento. A força de cisalhamento e matéria seca não foram afetadas ($P>0,05$) e a perda por cocção aumentou linearmente conforme incremento no PA

(P<0,01). O aumento do PA resultou em diminuição no rendimento de carne da carcaça (P<0,05) e aumento no rendimento de gordura (P<0,01).

Na avaliação das curvas de crescimento, o ganho diário de músculo apresentou ponto máximo aos 99,6 e 88,2 kg (377,3 e 410,6 g/dia) em machos e fêmeas, respectivamente. Uma vez que usualmente o ponto de máxima deposição proteica ocorre entre 60 e 80 kg, os resultados demonstraram que a genética avaliada possui características tardias. O ganho diário de gordura aumentou cubicamente nos machos (P<0,05), sendo que entre os 75 e 125 kg o aumento observado foi constante. Após 125 kg, percebeu-se forte tendência de aumento do ganho diário de gordura dos machos. Nas fêmeas, o ganho diário de gordura foi linear (P<0,001) durante todo o período avaliado. Aos 130 kg, os valores estimados de ganho de gordura foram de 269,5 e 218,4 g/dia para machos e fêmeas, respectivamente. O ganho de peso diário aumentou quadraticamente com ponto de máxima aos 96 e 98,8 kg (0,960 e 0,895) em machos e fêmeas, respectivamente. Com a utilização do INRAPORC®, percebeu-se que aos 70kg de peso vivo os machos e fêmeas apresentaram maior necessidade de lisina: 16,30 e 15,30 g/dia, respectivamente. Uma vez que o software utiliza o conceito de proteína ideal, os demais aminoácidos também apresentaram maior necessidade nessa faixa de peso.

Conclui-se que os suínos da genética avaliada devem ser abatidos acima de 100 kg quando o objetivo é aumentar os níveis de gordura intramuscular e subcutânea. A genética demonstrou crescimento tardio, mas com altas taxas de deposição de tecido muscular e elevada capacidade de acumular gordura aos 130 kg, o que sugere o uso dessa genética para a produção de produtos curados ou fermentados. A maior necessidade de lisina para a genética avaliada ocorre aos 70 kg de peso vivo nos machos e fêmeas.

Palavras-chave: Curvas de crescimento. Suínos pesados. INRAPORC®. Moura. Necessidades nutricionais.

ABSTRACT

Moura is a Brazilian locally adapted breed possibly derived from Iberian breeds and was widespread in southern Brazil in the first decades of the 20th century. This breed was used as energy source and for food preservation and cooking due to the high capacity of fat accumulation. Since there is lack of information on crossbred Moura pigs, the aim of the study was to evaluate the growth performance, cacass traits, meat quality, cut yields, growth curves and nutritional needs of crossbreed pigs with 29.7% Duroc, 15.6% Pietrain, 17.2% Large White, 25% Landrace, and 12.5% Moura. To evaluate performance, carcass traits and meat quality, 131 barrows and gilts were evaluated at 100, 115 and 130 kg of live weight. To evaluate cut yields, 8 pigs from each slaughter weight (100, 115 and 130 kg) were evaluated and the growth curves were evaluated in 56 pigs slaughtered at 22, 35, 60, 80, 100, 115 and 130 kg of live weight. The nutritional needs were estimated by INRAPORC®, which was calibrated with the consumption data of 8 barrows and 16 gilts. Pigs were housed by sex, with 3-4 animals per pen and the diets were fed *ad libitum* in semi-automated feeders. The evaluated crossbred had high levels of ether extract, backfat thickness and fat area, which was greater in barrows than in gilts ($P<0.01$) and increased linearly with SW ($P<0.01$). Shear force and dry matter were not affected ($P>0.05$) and cooking loss increased with SW ($P<0.01$). Increasing SW resulted in lower carcass meat yield ($P<0.05$) and greater fat yield ($P<0.01$). When evaluated the growth curves, the muscle daily gain showed maximum point at 99.6 and 88.2 kg (377.3 and 410.6 g/day) for barrows and gilts and the fat daily gain showed higher values at 130 kg in barrows and gilts (269.5 and 218.4 g/day, respectively). The average daily weight gain increased quadractilly with the maximum point at 96 and 98.8 kg (0.960 and 0.895) in barrows and gilts, respectively. The lysine need estimated by INRAPORC® increased until 70 kg in barrows and gilts: 16.30 and 15.13 g/day, respectively and, as consequence, the needs of other amino acids increased until this weight range. It was concluded that pigs from this genetic line should be slaughtered above 100 kg when aiming to increase intramuscular and subcutaneous fat. The evaluated crossbreed showed characteristics of late breeds, but high muscle deposition and high capacity to accumulate fat at 130 kg, which may suggest the use of this crossbreed for dry-cured or fermented products. In addition, the lysine need estimated by INRAPORC® increased until 70 kg in barrows and gilts.

Key-words: Growth curves. Heavy pigs. INRAPORC®. Moura breed. Nutritional needs.

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LIST OF ABREVIATIONS, ACRONYMS AND SYMBOLS

ADFI - Average daily feed intake

ADWG - Average daily weight gain

BDG - Bone daily gain

BFT - Backfat thickness

CY - Carcass yield

EIAM - Energy intake above maintence

FDG - Fat daily gain

FCR - Feed conversion ratio

HCW - Hot carcass weight

LD - Loin depth

LEA - Loin eye area

MDG - Muscle daily gain

SDG - Skin daily gain

SW – Slaughter weight

US – Ultrasound

VDG - Viscera daily gain

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INTRODUCTION

Modern pig lean genotypes commonly used in Brazil exhibit low intra and extra muscular fat, which may worsen juiciness, flavor and tenderness of pork. In addition, low levels of intramuscular and subcutaneous fat may detriment the production of dry cured or fermented products. In this context, the production of pork with higher levels of fat becomes a consumer demand.

Some Brazilian locally adapted breeds, like Moura, have high ability for fat deposition and the use of these breeds in crosses may improve carcass and pork quality due to the increase of fat deposition. Moura breed was widespread in the southern of Brazil during the first decades of the 20th century, and derived from Iberian breeds. Nowadays, Moura is in risk of extinction and the maintenance of this breed is essential for the preservation of local genetic material and biodiversity. In the present study, Moura breed was used in a cross with the goal of improving pork and carcass quality. The evaluations were performed in barrows and gilts, at different slaughter weights.

This thesis was split into four chapters. In the first one, the potential of growth performance, carcass traits, meat quality and cut yields of pigs slaughtered at 100, 115 and 130 kg in live weight were discussed. In chapter two, the tissues growth was evaluated in 56 pigs slaughtered at 22, 35, 60, 80, 100, 115 and 130 kg in live weight. In the third chapter, the software INRAPORC® was used to estimate the amino acid needs of a diet formulated by INRAPORC®. Finally, in chapter 4, the final considerations are presented.

CHAPTER 1 - GROWTH PERFORMANCE, CARCASS TRAITS AND MEAT QUALITY OF MOURA CROSSBRED PIGS SLAUGHTERED AT DIFFERENT WEIGHTS

Abstract

Moura is a Brazilian locally adapted breed characterized by rusticity and high ability for fat production. In order to improve carcass and pork quality by the inclusion of Moura breed, the potential growth performance, carcass traits, cut yield and meat quality of crossbred pigs (29.7% Duroc, 15.6% Pietrain, 17.2% Large White, 25% Landrace, and 12.5% Moura) were evaluated. To fulfill this goal, 131 pigs slaughtered at 100, 115 and 130 kg of live weight were used. Average daily feed intake, feed conversion ratio and fat yield increased ($P<0.05$), whereas average daily gain and carcass meat yield decreased ($P<0.05$), as slaughter weight (SW) increased. The evaluated crossbred had high intramuscular fat and dry matter content, backfat thickness and fat area, which were greater in barrows than in gilts ($P<0.01$) and increased linearly with SW ($P<0.01$). Shear force was not affected ($P>0.05$) and cooking loss increased with SW ($P<0.01$). Pigs from this genetic line should be slaughtered above 100 kg when aiming to increase intramuscular and subcutaneous fat with little effect on other meat quality traits.

Index terms: Moura breed, heavy pigs, carcass traits, pork quality, cuts.

1.1. Introduction

Until the beginning of the 1960s, the main product derived from pig production in Brazil was lard, which was used as energy source and for food preservation and cooking. Because of the increasing industrial production of vegetable oils, meat production became the central goal of pig production systems (FÁVERO and FIGUEIREDO, 2009), and genetic improvement programs started to be implemented to increase lean meat yield. In Brazil, this process led to the replacement of local breeds known for their high lard production by leaner breeds, such as Duroc, Landrace, Large White, and Pietrain. As consequence, the modern lean genotypes commonly used in Brazil exhibit low intra- and extra-muscular fat (BERTOL et al., 2015; OLIVEIRA et al., 2015).

Duroc and Moura are the two swine breeds most prone to improve meat quality in the crossbred pigs in Brazil, and such crossbreds are suitable for less intensive production systems. The Duroc breed has been introduced in Brazil regularly from the USA since the 1950 decade. The Moura breed was widespread in southern Brazil in the first decades of the 20th century, possibly derived from Iberian breeds (FÁVERO et al., 2007). After the second half of the 18th century, the meat and bacon produced by those pigs were a major food source for the cattle drivers in that region (LESSA, 1984), as well as in Jesuit-Guarani settlements in the west of the southern Brazilian states that survived until the Treaty of Madrid, in January of 1750.

Therefore, the Moura is probably the Brazilian locally adapted breed that suffered the greatest influence from the Iberian breeds from Spain. The maintenance of this breed in the Brazilian pig herd is essential for the preservation of local genetic material and biodiversity, and may contribute for the production of more resistant pigs adapted to local conditions (Fávero et al., 2007). Furthermore, local breeds may help to maintain biodiversity and sustainable agricultural production (FRANCO and LORENZO, 2013).

In intensive production systems, pure Moura pigs grow slower than modern swine genotypes and reduce the performance of crossbred pigs, due to its high potential for fat deposition (BERTOL et al., 2010). In comparison with modern lean genotypes, Moura pigs have twice the backfath thickness and lower loin depth and lean percentage (FÁVERO et al., 2007). Because of the high potential for fat deposition, the Moura breed can contribute for the production of better quality pork with higher intramuscular fat content or for the production of cured or fermented raw products (BERTOL et al., 2010) in crossbreeding schemes.

Despite the existing information on Duroc crossbreds there is lack of information on crossbred Moura pigs, so, this study aimed to evaluate the potential of growth performance, carcass traits, meat quality and cut yields of crossbred pigs with 29.7% Duroc, 15.6% Pietrain, 17.2% Large White, 25% Landrace, and 12.5% Moura genetic composition, slaughtered at 100, 115, or 130 kg live weight.

1.2. Materials and methods

Animals and management

The protocol of this experiment was approved by the Committee of Ethics on Animal Use for Research of Embrapa Swine and Poultry (protocol n. 007/2010). The experiment was carried out in 2013 in the facilities of the Brazilian Agricultural Research Corporation, in Concórdia, SC, Brazil. In total, 68 barrows and 63 gilts, sired by 59.4% Duroc, 31.2% Pietrain and 9.4% Large White sires farrowed by 50% Landrace, 25% Large White and 25% Moura sows, slaughtered at 100, 115, or 130 kg of live weight, were evaluated. The genetic lines came from the Embrapa swine breeding project and the experimental pigs belonged to the crossbreeding scheme designed to improve meat quality by the inclusion of the Moura breed. Pigs were housed by sex, with 3-4 animals per pen, totalizing 17 pens for barrows and 17 for gilts (9, 15 and 10 pens for the slaughter weights of 100, 115 and 130 kg, respectively). At the start of the experiment, pigs weighed, on average, 22.92 ± 2.65 kg and were 52-64 days old. Diets were formulated to attend or exceed the nutritional requirements of National Research Council (NRC, 2012), according to live weight ranges (Table 1) and were fed *ad libitum* in semi-automated feeders.

TABLE 1 - MAIN INGREDIENTS AND EXPECTED DIET NUTRITIONAL VALUES FED TO THE PIGS AS A FUNCTION OF LIVE WEIGHT RANGE.

Item	Live weight range, kg			
	22 - 60	60 - 80	80 - 115	115 - 130
Ingredients, %				
Corn	71.10	74.48	77.86	82.27
Soybean meal	23.50	21.06	18.13	14.26
Soybean oil	1.61	1.07	0.85	0.60
Dicalcium phosphate	1.27	1.11	0.99	0.81
Limestone	1.05	0.82	0.75	0.72
Salt	0.29	0.30	0.30	0.31
Amino acids*	0.34	0.37	0.34	0.25
Other**	0.84	0.78	0.78	0.78
Expected levels				
Crude protein, %	17	15.8	14.69	13.18
Metabolizable energy, kcal/kg	3260	3260	3260	3260
Calcium, %	0.7	0.62	0.56	0.5
Total phosphorus, %	0.53	0.51	0.48	0.44
Available phosphorus, %	0.35	0.31	0.28	0.24
Crude fiber, %	3.78	2.58	2.46	2.3
Lysine, %	1.07	0.99	0.9	0.77

*: L-lysine, L-threonine, L-tryptophan, DL-methionine; ** vitamin, trace mineral, and choline sulfate premix

All animals were submitted to the same management. The feed offered per pen and pigs were weekly weighed. The average daily feed intake and fed conversion rate were estimated for each pen. Pigs (n=131) were slaughtered based on live weight mean per pen in 14 different days between July and October. On the day of slaughter, in the early morning pigs were transported in a truck with body designed for this purpose, after twelve hours of feed fasting, and slaughtered after three hours of lairage in the slaughterhouse, in two different plants located approximately 15 km from the farm (24 pigs slaughtered at plant 1 and 107 at plant 2). Average group live body weights (BW) of 99.79 ± 1.028 kg, 113.92 ± 0.99 kg, and 128.45 ± 1.10 kg were obtained for the 100, 115, and 130 kg target slaughter weights, respectively. Before loading, backfat thickness and loin depth were measured at the last rib, using an ultrasound apparatus (ALOKA SSD-500V), coupled with a linear array transducer (UST 5011-3.5 MHz) and managed via BioSoft Toolbox® software for Swine from Biotronics Inc.

Carcass evaluation

The pigs were stunned by electronarcosis and the slaughter was performed by bleeding the pigs in the horizontal position following the standard procedures of the slaughterhouse. The carcasses (n=131) were weighed to obtain hot carcass weight and stored in a chilling room at 2 to 4 °C for 24 hours. After that, backfat thickness was measured in the middle line of the left half carcasses at the first and last rib, and at the first sacral vertebra. The backfat mean was obtained by the average of three points. Loin eye area and fat area were drawn in a greaseproof paper at the last rib, according to the Brazilian Method of Pig Carcass Grading System (ABCS, 1973). Loin eye area and fat area were calculated by the software Rhinoceros® 4.0 (ROBERT MCNEEL and ASSOCIATES, 2007), using loin eye and fat area images scanned with a scale.

Cut yield and dissection

Cut yield was evaluated in the carcasses of four barrows and four gilts per group of slaughter weight, from the same pen, totaling 24 carcasses from the animals whose individual weight was closest to the group target slaughter weight. Average group live body weights (BW) of 105.15 ± 0.44, 115.57 ± 1.99 and 130.77 ± 3.24 kg were obtained for the 100, 115, and 130 kg target slaughter weights. Carcasses were fabricated 24h after slaughter. The carcasses were divided into primal cuts: ham, shoulder, loin and belly. Subsequently, the meat, fat, skin and bones of each cut were separated. The weights of cuts and their fractions were used to calculate cut yield (cut percentage relative to whole carcass), fraction yield (meat, fat, skin, and bone weight relative to cut weight), as well as whole carcass meat, fat, bone, and skin yield.

Meat quality

pH assessment was performed 45 minutes and 24 hours after slaughter (n=131), in the *longissimus thoracis* at the height of the last rib and in the *semimembranosus*, by insertion of an electrode (Hanna Instruments, FC 232D) coupled with a portable pH meter (Hanna Instruments, HI 99163). Twenty-four hours after slaughter, color by CIELAB color system (coordinates L*, a* and b*, Minolta Camera Ltd., Japan; illuminant D65; 0° viewing angle; 8 mm measuring area; illumination area of 11 mm diameter) was evaluated. Drip loss was evaluated in 12g-meat samples. Samples were weighed and stored in a flask with exudate-collecting column at 7ºC for 48h. At the end of this period, samples were re-weighed and drip loss was calculated as the difference between final and initial weight, and expressed as a percentage of initial weight (according to Correa et al., 2007).

Loin samples were collected for analysis of dry matter, ether extract, shear force, and cooking loss. These samples were transported to the laboratory, where they were stored at -20 °C for later analysis. Samples analyzed for ether extract and dry matter content were submitted to freeze-drying from -40 ºC to 20 ºC (Lyophilizer Liobrás, Model LP810), ground in a refrigerated mill (Foss Tecator 1095 - Knifetec Sample), and stored at -25ºC. Ether extract and dry matter were determined according to the methods recommended by Association of Official Analytical Chemists (AOAC, 1995).

Samples used for shear force and cooking loss analyses were thawed to 5 ºC for 24h, and then cooked in water bath until reaching 75 ºC. Cooking loss was calculated as the sample weight difference before and after cooking. After cooling to room temperature (~20 ºC), samples were cut in 1x1x2 cm pieces and placed perpendicularly to the direction of the muscle fibers in a Warner-Bratzler apparatus (TA-XT Plus, Stable Micro Systems) previously calibrated for 10 kg, with aluminum probe (HDP) and pre-test, post-test and test speed of 2.0 mm/s (AMSA, 1995).

Statistical analysis

Completely or block (pen) randomized experimental designs in a 3 x 2 factorial arrangement was applied, considering three slaughter weights (100, 115, or 130 kg) and two sexes (barrows or gilts). Data were submitted to analysis of variance using the GLM procedure of Statgraphics (StatPoint, 2005; Version XV; Herndon, VA), with 5% significance. For the variables analyzed considering the animal individually as replication (average daily weight gain, carcass and meat quality traits and cut yield measures), the qualitative effects of sex and pen and the quantitative linear and quadratic effects of slaughter weight, as well as the interaction between sex and the linear and quadratic terms of slaughter weight were tested. When the interaction with the quadratic term was not significant, the two remaining model options were tested: the linear term and its interaction with the sex factor (to evaluate the possibility of two different linear equations by sex); and the quadratic equation (linear and quadratic terms), without the interactions with the sex factor, evaluating in this case, the sex effect only on the intercept. The coefficients for sex and slaughter weight terms were obtained from the final model reached for each variable. For the variables analyzed per pen (average daily fed intake and fed conversion rate), the same procedures were performed without considering the qualitative effect of pen.

1.3. Results and discussion

Growth Performance

Feed intake was larger in barrows than in gilts ($P<0.001$; Table 2). The greater feed intake observed in barrows was expected and that agrees with previous reports (PEINADO et al., 2008; LATORRE et al., 2004; PIAO et al., 2004). Because of their greater feed intake, barrows had higher weight gain ($P<0.001$), as previously reported by Cisneros et al. (1996), who evaluated two genotypes: a commercial hybrid from a breeding company and a three-breed cross of Hampshire sires with Yorkshire X Duroc dams. Although expected, there was no influence of sex on feed conversion ratio ($P>0.05$).

Feed intake increased linearly with slaughter weight (SW): 5g/day for each kg increase in SW (Table 3). This value is half of that reported by Cisneros et al. (1996). However, weight gain decreased linearly with SW, worsening the feed conversion rate, as previously reported by other authors (LATORRE et al., 2008; PEINADO et al., 2008; PIAO et al., 2004). Typical growth performance of gilts and barrows estimated from the curves of ME intake and protein deposition of NRC (2012), slaughtered at 130 kg of live weight, had similar feed intake and daily gain.

The calculated regression coefficients for growth performance were low and, as observed in other crosses and genetic lines, the results suggested little influence of SW on these parameters in the range of age and weight evaluated. In the present study, animals were fed ad libitum and diets were formulated with enough nutrient levels for the animals to express their genetic potential.

Carcass

Gilts presented greater loin area (P<0.001; Table 2) than barrows, which is also described in other crosses (PIAO et al., 2004; BEATTIE et al., 1999; MARTIN et al., 1980) and it is attributed to the fact that gilts tend to deposit more muscle than barrows. Accordingly, backfat thickness values measured *in vivo* and in three different points of the carcass and fat area were greater in barrows (P<0.05) than in gilts, agreeing with other studies (LATORRE et al., 2008; PEINADO et al., 2008; LATORRE et al., 2004). As observed in other crossbreeds, the greater barrows feed intake and the absence of testicular steroids are the main factors responsible for their higher fat deposition.

Gilts had greater carcass yield than barrows (P<0.01), which increased linearly with SW in both sexes (P<0.001; Table 3). As pigs age, carcass growth rate is proportionally greater than viscera growth rate (GU et al., 1992). The carcass yield of pigs slaughtered with 130 kg SW was considerably greater, which could be explained by the accumulation of subcutaneous fat in the carcass with aging. Other studies reported a linear increase of carcass yield as a response to aging and SW, with values ranging between 0.032 and 0.086% per kg of SW increase (FRANCO et al., 2016; LATORRE et al., 2008; CISNEROS et al., 1996; IRGANG and PROTAS, 1986) in pigs from different crossbreds slaughtered between 100 and 160 kg.

A linear increase (P<0.001) of 0.220 mm per kg of SW increase was observed in the backfat thickness measured at the last rib. This value is in the range of values reported by Latorre et al. (2004) and Latorre et al. (2008) in Duroc, Landrace, Large White and Pietrain crossbreeds intended for dry cured ham production and slaughtered between 116 and 140 kg: 0.240 and 0.210 mm, respectively. The mean of backfat in barrows and gilts slaughtered at 130 kg was 28.41 mm, which was similar to the value observed by Latorre et al. (2004) (27.0 mm) in pigs slaughtered at 133 kg.

The linear increase in backfat thickness measured by ultrasound at the last rib, on the day before slaughter, was less pronounced than the values observed in the carcass: 0.137 mm per kg of SW increase (P<0.001), which was also reported by Dutra Jr. et al. (2001) in Camborough® 22 pigs. The fat area increase of 0.385 cm^2 per kg SW (P<0.001) was greater than that reported by Irgang and Protas (1986), who obtained an increase of 0.242 cm^2 (R^2=80.4%) per kg of SW in Landrace x Large White crossbred pigs slaughtered between 80 and 140 kg live weight.

The backfat thickness measured by ultrasound, of barrows and gilts slaughtered at 130 kg of live weight were greater than the values estimated using the curves of ME intake and protein deposition reported at the NRC (2012), which are 20.9 and 17.5 mm, respectively. The greater carcass fat observed in this study demonstrates the capability of the Moura and the Duroc breeds to deposit subcutaneous fat, despite the small proportion of Moura (12.5%) in the composition of the genotype evaluated. These results are supported by the findings of Bertol et al. (2010), who reported higher backfat thickness in barrows containing 50% and 25% of Moura compared with crossbreds of a lean genotype, and Favero et al. (2007) who found twice as much backfat thickness in Moura than in a lean genotype.

Loin depth and loin eye area increased linearly with SW (P<0.001). In other crossbred and genetic lines linear increases of 0.37 (DUTRA Jr. et al., 2001) and 0.18 cm^2 (CISNEROS et al., 1996) were reported on loin area.

TABLE 2 - MEANS FOR THE EFFECTS OF SEX AND SLAUGHTER WEIGHT ON GROWTH PERFORMANCE AND CARCASS TRAITS OF BARROWS AND GILTS SLAUGHTERED IN THE RANGE OF 100 TO 130 KG.

Parameter	Barrows			Gilts			*P*-value[1]		rSD
	100	115	130	100	115	130	Sex	Linear	
N	12	33	18	24	24	20	-	-	-
Initial weight, kg	21.13	24.10	22.64	23.26	22.48	22.40	-	-	-
Final weight, kg	102.36	113.82	128.88	98.51	114.05	128.06	-	-	-
Initial age, days	57.75	61.42	64.11	63.42	59.12	64.15	-	-	-
Final age, days	143.08	157.09	186.89	149.08	168.12	196.75	-	-	-
ADFI, kg	2.60	2.75	2.74	2.32	2.39	2.49	<0.001	0.005	0.11
ADWG, kg	0.96	0.95	0.87	0.89	0.85	0.80	<0.001	<0.001	0.05
FCR	2.70	2.88	3.15	2.61	2.81	3.10	NS	<0.001	0.10
HCW, kg	73.32	82.19	97.19	70.81	83.91	97.55	0.004	<0.001	2.15
CY (%)	71.63	71.74	75.37	71.86	73.38	76.14	0.005	0.013	1.77
LEA, cm^2	36.43	42.07	42.92	43.77	50.54	48.06	<0.001	<0.001	4.66
Fat area, cm^2	24.49	29.93	35.30	20.18	24.66	32.12	<0.001	<0.001	4.28
LD US, mm	63.55	67.59	71.34	64.40	69.05	72.53	NS	<0.001	4.23
BFT 1R, mm	32.56	36.93	40.88	31.65	30.86	39.22	0.002	0.001	5.40
BFT LR, mm	24.49	26.21	30.16	20.60	21.77	26.84	<0.001	<0.001	3.99
BFT 1S, mm	23.54	24.80	27.25	19.22	18.56	24.76	<0.001	0.002	4.02
BFT mean, mm	26.86	29.32	32.77	23.82	23.73	30.27	<0.001	<0.001	3.79
BFT US, mm	22.23	22.67	25.67	16.64	17.57	22.70	<0.001	<0.001	3.57

[1] = quadratic term, interaction between sex and linear term of the weight and interaction between sex and quadratic term of the weight were not significant for any variable (P>0.06); rSD = residual standard deviation; N = Number of animals; ADFI = average daily feed intake; ADWG = average daily weight gain; FCR = feed conversion ratio; HCW = hot carcass weight; CY = carcass yield; LEA = loin eye area; LD US = loin depth measured *in vivo* by ultrasound; BFT 1R = backfat thickness in the first rib; BFT LR = backfat thickness in the last rib; BFT 1S = backfat thickness in the first sacral vertebra; BFT mean = average of BFT 1R, BFT LR and BFT 1S; BFT US = backfat thickness measured by ultrasound; NS = Not significant (P>0.05).

TABLE 3 - PARAMETERS OF THE REGRESSION POLYNOMIAL ANALYSIS OF LIVE PERFORMANCE AND CARCASS TRAITS OF BARROWS AND GILTS SLAUGHTERED IN THE RANGE OF 100 TO 130 KG.

Dependent variable	Parameter estimate			R^2
	Intercept		Linear	
	Barrows	Gilts		
ADFI, kg	2.088	1.784	0.005	71.48
ADWG, kg	1.279	1.189	-0.003	57.54
FCR	0.972		0.017	78.86
HCW, kg	5.642	6.774	0.788	96.97
CY, %	67.496	68.409	0.046	64.00
LEA, cm²	8.272	15.115	0.286	57.22
Fat area, cm²	-14.295	-18.183	0.385	68.59
LD US, mm	41.663		0.232	47.79
BFT 1R, mm	15.859	12.623	0.185	47.10
BFT LR, mm	1.758	-2.103	0.220	53.82
BFT 1S, mm	9.676	5.431	0.135	46.15
BFT mean, mm	3.666	1.946	0.210	44.54
BFT US, mm	9.097	5.317	0.180	57.35

ADFI = average daily feed intake; ADWG = average daily weight gain; FCR = feed conversion ratio; HCW = hot carcass weight; CY = carcass yield; LEA = loin eye area; LD US = loin depth measured *in vivo* by ultrasound; BFT 1R = backfat thickness in the first rib; BFT LR = backfat thickness in the last rib; BFT 1S = backfat thickness in the first sacral vertebra; BFT mean = average of BFT 1R, BFT LR and BFT 1S; BFT US = backfat thickness measured by ultrasound.

Cut yield

Sex influenced the meat and fat yields of carcass, showing that gilts had greater meat yield (P<0.01; Table 4) and lesser fat yield (P<0.01) than barrows. As observed in the present crossbred, other authors did not observe any effect of sex on shoulder weight (FRANCO and LORENZO, 2013; PEINADO et al., 2008; CISNEROS et al., 1996). Gilts had higher ham and loin weight (P<0.05). An interaction between sex and SW was observed on belly weight and belly yield (P<0.05). Barrows had higher linear coefficient than gilts on belly weight (Table 5) due to the to the greater fat content of this cut in barrows. As consequence, belly yield increased in barrows and decreased in gilts.

The whole-carcass meat yield decreased (P<0.01) and the fat and bone yield increased (P<0.01) with SW, but the skin yield was not affected (P>0.05). It was observed that increasing the slaughter weight of the pigs derived from the evaluated genetic cross, from 100 to 130 kg, increased carcass fat to meat ratio, which was also influenced by sex, as demonstrated by the increasing backfat thickness and fat area. These findings are consistent with those reported by Irgang and Protas (1986) and Cisneros et al. (1996), who found that meat yield decreased as pig slaughter weight increased from 80 to 160 kg.

The increase in shoulder weight (0.147 kg per kg of SW increased) observed in the present study is consistent with those reported in other crosses, ranging from 0.090 to 0.180 kg (LATORRE et al., 2008; LATORRE et al., 2004; DUTRA JR et al., 2001; CISNEROS et al., 1996; IRGANG and PROTAS, 1986; MARTIN et al., 1980). However, the increase in other cuts was higher than the values reported in previous studies, which ranged between 0.086 and 0.195 kg for the ham (LATORRE et al., 2008; LATORRE et al., 2004; DUTRA JR et al., 2001; CISNEROS et al., 1996), and between 0.036 and 0.117 kg for the loin (LATORRE et al., 2008; DUTRA JR et al., 2001; CISNEROS et al., 1996; MARTIN et al., 1980). The differences may be due to variation in cut patterns and in tissue growth rate among the studies.

The ham weight is one of the parameters used in dry-cured ham production. In Brazil, the legislation for Parma type ham production demands that the slaughter be done at a minimum live weight of 130 kg and the ham must weigh at least 9 kg

(BRASIL, 2000). As the present crossbred satisfies the Brazilian laws requirements, these pigs can be slaughtered at 130 kg if the aim is to produce Parma type ham.

Ham and loin yields were not affected by SW (P>0.05) and, despite significant, the slope observed for shoulder yield was low, suggesting little influence of aging on these parameters.

Meat quality

The intramuscular fat and dry matter content were largely affected by sex. Loin dry matter and ether extract content were greater in barrows (P<0.01; Table 6), which is due to the substitution of intramuscular water by lipid (BEATTIE et al., 1999). Consequently, barrows had lesser cooking loss (P<0.001) and shear force (P<0.01). The loin and ham of barrows had greater b* values (P<0.05), which indicate yellowness, but in other studies it was not observed any effect of sex on meat color (CORREA et al., 2006; LATORRE et al., 2004). Other studies did not report effect of sex on pH45 and pH24 (CORREA et al., 2006; LATORRE et al., 2004; CISNEROS et al., 1996;) or drip loss (CORREA et al., 2006; BEATTIE et al., 1999).

The pH24 values observed in ham and loin in barrows and gilts of all ages and slaughter weights are within the range of normal quality meat (ultimate pH >5.5 and <5.8), according to Correa et al. (2007). Despite being significant, the calculated regression coefficient and the R^2 of pH45 on loin and ham were low (Table 7), revealing a weak effect of this coefficient.

It was not observed effect of SW on drip loss (P>0.05). Although Beattie et al. (1999) demonstrated that heavier carcasses need more time to chill, which could increase the drip loss, other factors influence drip loss more intensely, such as pH, chilling capacity of the plant and animal handling before slaughter.

Cooking loss is an important variable in the meat industry because it is one of the factors that influences juiciness (AASLYNG et al., 2003) and because of its potential to affect the direct weight losses in processed cooked products. In the present study, cooking loss slightly increased as SW increased (P<0.05), but this effect was not observed by other authors (FRANCO et al., 2016; CORREA et al., 2006; CISNEROS et al., 1996). The increase of a* values in ham (P<0.05) indicates that the meat of heavier pigs is redder, which favors the sale of the fresh meat. This is due to the high myoglobin content in the muscle of heavy pigs (LATORRE et al., 2004). Although there was no significant effect of SW on loin a* values (P=0.09), it was observed a trend of the loin meat to be redder. Loin and ham b* values decreased (P<0.05) and the L* values were not influenced (P>0.05) by SW, differently from the findings of Franco et al. (2016), Fábrega et al. (2011) and Latorre et al. (2004), who reported L* value reduction as SW increased.

The variables concerning meat quality are widely affected by initial and final pH. In the evaluated crossbred, the discreet influence of SW on pH was probably responsible for the slight changes observed on color, drip loss and cooking loss. However, it should be taken into account that, despite being submitted to the same management, the slaughtering were carried out in distinct times, and environmental factors may have a greater effect than slaughter weight on the pH values. The differences observed in the meat quality characteristics among the different studies are due to a number of factors including genetic influence, range of slaughter weight, pre-slaughter management, nutritional levels, and different assessment methodologies.

Shear force was not affected by SW (P>0.05). On the other hand, Correa et al. (2006) reported reduced meat soluble collagen content, and consequently, higher shear force values as aging in Duroc X (Landrace X Large White) crossbred. There was a linear increase in ether extract content as SW increased (P<0.001), showing high intramuscular fat content in the carcasses of pigs slaughtered with 130 kg. Although not significant (P=0.08), there is a trend to a quadratic increase in ether extract content with a strong increase when the slaughter weight increased from 115 to 130 kg (Fig 1). These results suggest that in the evaluated crossbred, the increase in SW did not affect negatively the meat quality traits. The increase in ether extract content was expected, since in animals fed ad libitum or under minimal restriction, older ages does entail increased fat deposition, which includes intramuscular fat, as reported by other authors (FRANCO et al., 2016; CANDEK-POTOKAR et al., 1998; WEATHERUP et al., 1998; CISNEROS et al., 1996).

TABLE 4 - MEANS FOR THE EFFECTS OF SEX AND SLAUGHTER WEIGHT ON CARCASS YIELD, CUT WEIGHT AND CUT YIELD OF BARROWS AND GILTS SLAUGHTERED IN THE RANGE OF 100 TO 130 KG.

Parameter	Barrows			Gilts			Significance[1]				rSD
	100	115	130	100	115	130	Sex	Linear	Quadratic	Sex x Linear	
N	4	4	4	4	4	4	-	-	-	-	-
Initial weight, kg	23.95	20.52	22.77	26.39	22.07	25.26	-	-	-	-	-
Final weight, kg	105.8	115.4	131.52	104.5	115.75	130.02	-	-	-	-	-
Initial age, days	64.5	60.0	65.5	66.25	57.0	66.75	-	-	-	-	-
Final age, days	148.5	165	192.5	150.25	169	200.75	-	-	-	-	-
Carcass											
Meat yield, %	58.08	55.12	52.60	61.29	57.22	60.99	0.003	0.021	NS	NS	3.27
Fat yield, %	27.21	31.32	34.97	25.32	29.06	25.21	0.007	0.008	NS	NS	3.70
Bone yield, %	11.19	10.08	9.43	10.31	10.64	10.93	NS	0.03	NS	NS	0.83
Skin yield, %	3.92	3.98	3.47	3.66	3.63	3.57	NS	NS	NS	NS	0.28
Shoulder											
Cut weight, kg	10.77	11.90	14.82	10.09	12.36	14.33	NS	<0.001	NS	NS	0.51
Cut yield, %	14.34	14.17	14.38	13.23	14.42	14.32	NS	0.02	0.03	NS	0.54
Ham											
Cut weight, kg	22.76	24.27	30.02	23.68	25.90	31.11	0.01	<0.001	NS	NS	1.17
Cut yield, %	30.31	28.88	29.16	31.05	30.25	31.02	0.016	NS	NS	NS	1.24
Loin											
Cut weight, kg	21.26	23.57	27.48	22.68	24.38	29.58	0.005	<0.001	NS	NS	1.31
Cut yield, %	28.30	28.07	26.67	29.69	28.43	29.38	0.009	NS	NS	NS	1.28
Belly											
Cut weight, kg	20.24	24.11	30.61	19.87	23.00	25.30	0.004	<0.001	NS	0.001	1.25
Cut yield, %	26.96	28.73	29.69	26.02	26.79	25.19	NS[2]	NS[2]	NS	0.019	1.20

[1] = interaction between sex and quadratic term of the weight was not significant for any variable (P>0.05); [2] = Although p>0.05, the interaction between sex and linear effect of slaughter weight was considered of greater importance; rSD = residual standard deviation; N = Number of animals; SW = Slaughter weight; NS = not significant (P>0.05).

TABLE 5 - PARAMETERS OF THE REGRESSION POLYNOMIAL ANALYSIS OF CARCASS YIELD, CUT WEIGHT AND CUT YIELD OF BARROWS AND GILTS SLAUGHTERED IN THE RANGE OF 100 TO 130 KG.

Dependent variable	Parameter estimate					R^2
	Intercept		Linear		Quadratic	
	Barrows	Gilts	Barrows	Gilts		
Carcass						
Meat yield, %	71.501	75.954	-0.138		-	46.00
Fat yield, %	9.658	5.171	0.183		-	45.99
Bone yield, %	14.345		0.033		-	20.40
Shoulder						
Cut weight, kg	-4.859		0.147		-	92.92
Cut yield, %	-16.586		0.503		-0.002	25.20
Ham						
Cut weight, kg	-6.105	-4.800	0.271		-	90.07
Loin						
Cut weight, kg	-6.758	-5.100	0.262		-	87.45
Belly						
Cut weight, kg	-19.76	-3.373	0.381	0.223	-	91.76
Cut yield, %	17.762	27.594	0.091	-0.014	-	62.93

TABLE 6 - MEANS FOR THE EFFECTS OF SEX AND SLAUGHTER WEIGHT ON MEAT QUALITY TRAITS OF BARROWS AND GILTS SLAUGHTERED IN THE RANGE OF 100 TO 130 KG.

Parameter	Barrows			Gilts			*P*-value [1]			rSD
	100	115	130	100	115	130	Sex	Linear	Quadratic	
N	12	33	18	24	24	20	-	-	-	-
Loin										
pH45	6.29	6.46	6.48	6.46	6.39	6.26	NS	0.008	0.006	0.19
pH24	5.71	5.77	5.76	5.75	5.71	5.73	NS	NS	NS	0.08
L*	45.97	46.73	46.68	46.66	46.34	47.26	NS	NS	NS	2.15
a*	3.17	3.42	4.27	3.63	3.87	4.24	NS	NS	NS	0.81
b*	3.35	2.63	2.52	3.76	1.51	1.51	0.006	0.003	NS	1.14
Drip loss, %	3.54	3.30	2.61	3.66	3.00	4.58	NS	NS	NS	1.80
Cooking loss, %	35.69	36.84	36.04	36.55	37.71	38.78	<0.001	0.007	NS	1.67
Shear force, N	30.98	30.83	30.78	31.91	41.84	31.09	0.006	NS	NS	9.67
Dry matter, %	24.87	25.26	27.34	24.52	25.28	26.32	<0.001	NS	NS	0.77
Ether extract	1.77	2.01	3.06	1.68	1.85	2.20	0.009	<0.001	NS	0.73
Ham										
pH45	6.36	6.52	6.40	6.49	6.45	6.31	NS	0.01	<0.001	0.17
pH24	5.81	5.81	5.76	5.84	5.75	5.73	NS	NS	NS	0.08
L*	43.65	44.78	45.53	43.62	44.53	45.13	NS	NS	NS	2.35
a*	5.26	6.02	7.09	5.98	5.77	6.88	NS	0.04	NS	1.26
b*	3.13	3.18	3.74	3.63	2.09	2.02	<0.001	0.03	NS	1.27
Drip loss, %	3.30	3.24	3.52	3.82	4.02	5.08	0.002	NS	NS	1.80

[1] = interaction between sex and linear term of the weight and interaction between sex and quadratic term of the weight were not significant for any variable (P>0.11); rSD = residual standard deviation; N = Number of animals; pH45 = pH 45 minutes; pH24 = pH 24 hours; N = Newton; NS = Not significant (P>0.05).

TABLE 7 - PARAMETERS OF THE REGRESSION POLYNOMIAL ANALYSIS OF MEAT QUALITY TRAITS OF BARROWS AND GILTS SLAUGHTERED IN THE RANGE OF 100 TO 130 KG.

Dependent variable	Parameter estimate				R^2
	Intercept		Linear	Quadratic	
	Barrows	Gilts			
Loin					
pH45	9.551		-0.060	0.0002	39.74
b*	6.976	6.381	-0.036	-	47.51
Cooking loss, %	30.420	31.942	0.050	-	38.05
Ether extract	-0.264	-0.640	0.022	-	17.86
Ham					
pH45	10.582		-0.073	0.0003	42.60
a*	3.033		0.027	-	31.87
b*	6.758	5.927	-0.029	-	35.20

pH45 = pH 45 minutes; pH24 = pH 24 hours; N = newton

When the slaughter is performed up to about 110 kg, the effect of SW on ether extract (EE) seems to be of little importance in this genotype (Figure 1), although the backfat thickness measured by ultrasound (BF-US) increased in barrows and gilts in this weight range (Figure 2). These results indicate that the fat deposition follow different patterns in extra and intramuscular tissues.

FIGURE 1 - RELATIONSHIP BETWEEN SLAUGHTER WEIGHT (SW) AND ETHER EXTRACT (EE) ($P<0.01$, R^2=17.86%). FOR BARROWS, EE = -0.264 + 0.022*SW. FOR GILTS, EE = -0.640 + 0.022*SW.

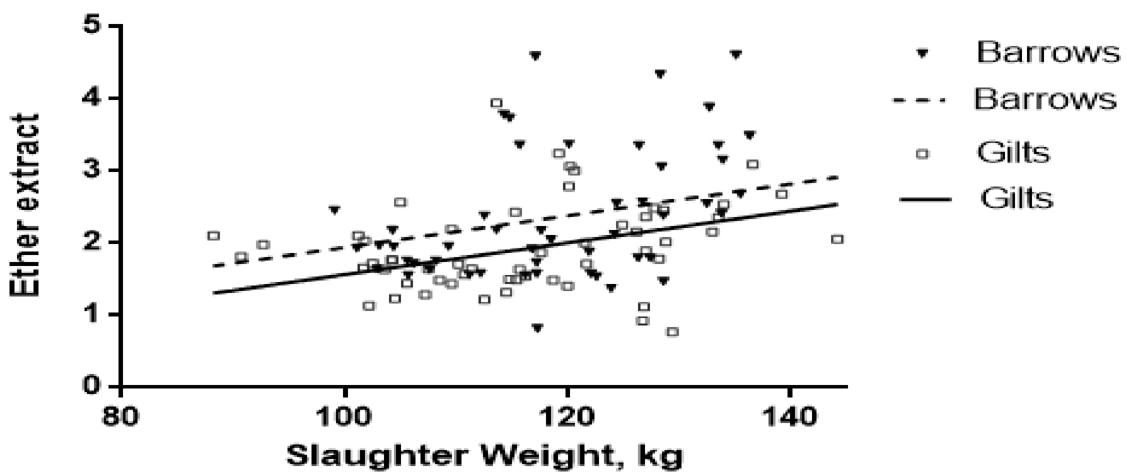
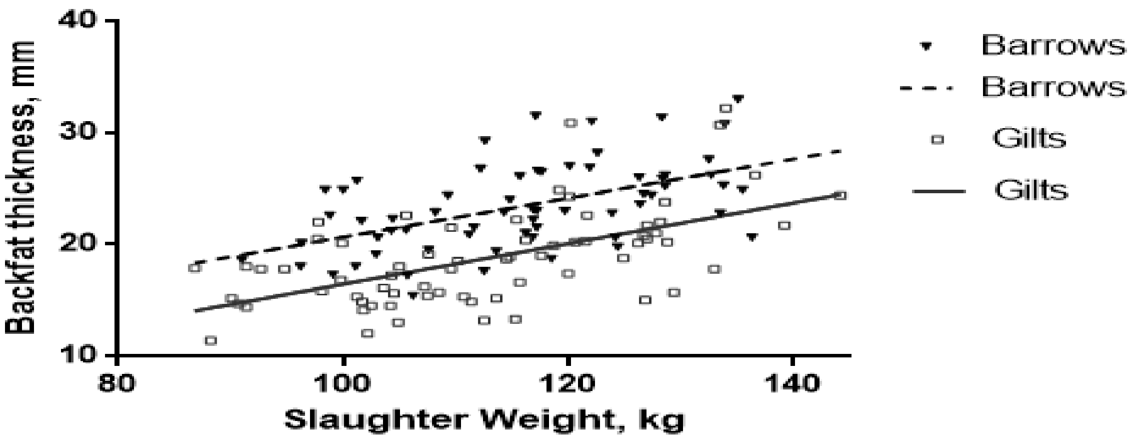
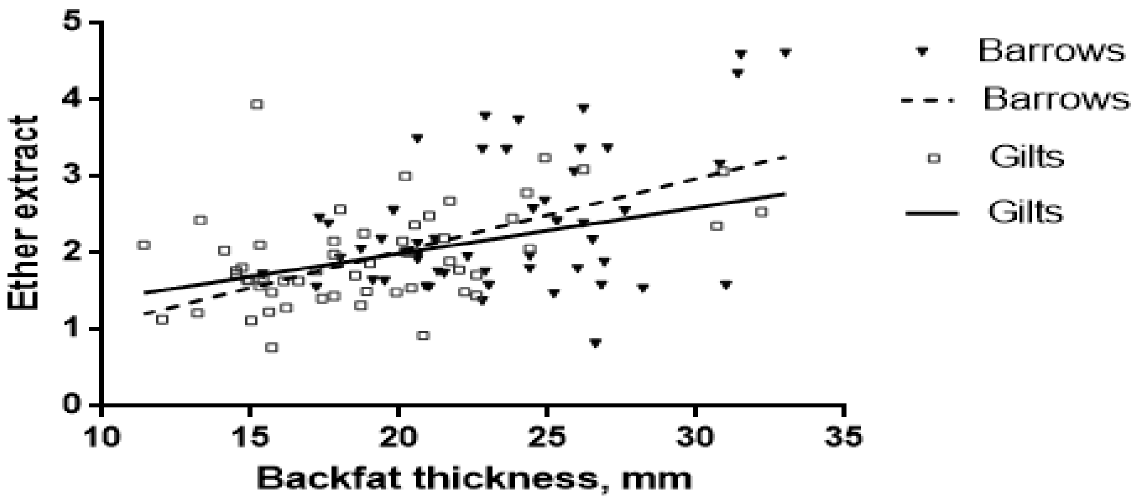


FIGURE 2 - RELATIONSHIP BETWEEN SLAUGHTER WEIGHT (SW) AND BACKFAT THICKNESS (BFT US) ($P<0.001$, R^2=59.66%). FOR BARROWS, BFT US = 7.581+ 0.137*SW. FOR GILTS, BFT US = 3.356 + 0.137*SW



After the BF-US reached 20 mm in barrows and gilts, higher values of EE were observed (Figure 3), which suggested that, in order to obtain a meat with high levels of intramuscular fat a minimum level of backfat must be deposited in this genotype. According to Font-i-Furnols et al. (2012), the minimal level of intramuscular fat for consumers who prefer fat or lean pork are 3.4 and 2.2%, respectively. Considering the characteristics of the genotype evaluated in the present study, in order to achieve these values of intramuscular fat it would be necessary a BF-US of 34.57 and 21.94 mm, respectively, in barrows and 43.53 and 23.53 mm, respectively in gilts.

FIGURE 3 - RELATIONSHIP BETWEEN BACKFAT THICKNESS (BFT US) AND ETHER EXTRACT (EE) (P<0.001, R^2=25.21%). FOR BARROWS, EE = 0.116 + 0.095*BFT US. FOR GILTS, EE= 0.788 + 0.060*BFT US.



The average intramuscular fat in barrows and gilts slaughtered at 130 kg was 2.61%, which is similar to the values reported by Latorre et al. (2004) and Virgili et al. (2003): 2.7 and 2.45% on loin of barrows and gilts slaughtered with 133 and 145 kg, respectively, in crosses intended for dry-cured ham production. Franco and Lorenzo (2013) reported lower values of intramuscular fat in Celta pigs slaughtered at 140 kg: 2.12 and 1.67 for barrows and gilts, respectively. The introduction of the Duroc and the Moura breeds in the genotype evaluated in this study may have contributed to these high levels of intramuscular fat, since Duroc and Moura are breeds with great capacity of extra- and intramuscular fat accumulation, as reported by Bertol et al. (2010). However, the comparison of the intra- and extra muscular fat content with those reported in other studies (FRANCO and LORENZO, 2013; VIRGILI et al. 2013; LATORRE et al., 2008; LATORRE et al., 2004; DUTRA JR et al., 2001; IRGANG and PROTAS, 1986), indicate that nutritional management, particularly energy allowance, should be considered, because dietary energy restriction may limit fat deposition.

Higher intramuscular fat content may favor the sale of fresh pork derived from animals of this cross, as it may positively impact meat juiciness, flavor (FERNANDEZ et al., 1999) and tenderness (TEYE et al., 2006). However, it should be taken into account that the preferred degree of marbling in pork may vary along countries

(NGAPO et al., 2007) and other factors can influence more intensely the eating quality, like pH (LONGERGAN et al., 2014) and the end point of cooking (RINCKER et al., 2004).

In Czech Republic (DOSTÁLOVÁ et al., 2012), China (JIANG, et al., 2012), Germany (SCHWALM et al., 2013), Estonia (POLDVERE et al., 2015) and Spain (FRANCO et al., 2014) studies showed the effect of using breeds like Prestice Black Pied, Meishan, Saddleback, Duroc and Celta in crossbreeding programs to improve the meat quality traits of the pork offered to local and to special markets and as in this work intramuscular fat and other meat quality traits were favored by such breeds.

1.4. Conclusions

The slaughtering of pigs of this genotype at heavy weights should be done when the objective is to increase intra muscular and subcutaneous fat with little effect on other meat quality traits. Although the slight worsening in growth performance with increasing slaughter weight in this genotype indicates an increase in production costs, the higher intramuscular fat content may favor the marketing of fresh pork and the processing of dry cured products.

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CHAPTER 2 - TISSUE GROWTH OF MOURA CROSSBRED PIGS SLAUGHTERED BETWEEN 22 AND 130 KG.

Abstract

Moura breed was widespread in southern Brazil in the first decades of the 20th century and is a rustic breed, characterized by high amounts of intra- and extramuscular fat accumulation and slow growth rate. Since little is known about the use of the Moura pig in crossbreeds, the aim of this study was to evaluate the tissue growth of crossbred pigs comprised of 29.7% Duroc, 15.6% Pietrain, 17.2% Large White, 25% Landrace, and 12.5% Moura. To that end, 56 barrows and gilts were slaughtered at 22, 35, 60, 80, 100, 115 and 130 kg of live weight and their tissues were dissected into muscles, fat, bones, skin and viscera. The average daily weight gain increased quadractilly with the maximum point at 96 and 98.8 kg (0.960 and 0.895) in barrows and gilts. The muscle daily gain showed maximum point at 99.6 and 88.2 kg (377.3 and 410.6 g/day) for barrows and gilts and the fat daily gain showed higher values at 130 kg in barrows and gilts (269.5 and 218.4 g/day, respectively). The evaluated crossbreed showed slow growth, but high muscle deposition and high capacity to accumulate fat at 130 kg, which may suggest the use of this crossbreed for dry-cured or fermented products.

Key words: fat gain, heavy pigs, muscle gain.

2.1. Introduction

Modern lean genotypes are characterized by fast muscle growth and low fat levels (BERTOL et al., 2015), which may worsen sensorial attributes (DASZKIEWICZ et al., 2005; FERNANDEZ et al., 1999a), consumer acceptance (FERNANDEZ et al., 1999b) and detriment the production of dry cured products (BOSI and RUSSO, 2004). Until the 1970s, the aim of the pig production was fat, which was used as an energy source and for food preservation. Subsequently, with the beginning of the soybean oil production and the popularization of electric power, pig production started to aim lean. In this process, locally adapted Brazilian breeds intended for fat production were replaced by foreign breeds specialized in lean production (IRGANG, 2008). The demand for lean led to an increase in 45% of lean tissue deposition efficiency and a decrease of 15% in the time needed to reach the slaughter weight between 1980 and 2005 (FIX et al., 2010).

Among the Brazilian breeds, Moura probably is derived from Iberian pigs (FÁVERO et al., 2007) and were widespread in southern Brazil in the first decades of 20th century. This breed has low growth performance due to the high potential of fat deposition (BERTOL et al., 2010; FÁVERO et al., 2007), which may contribute to dry-cured or fermented production when used in crosses (BERTOL et al., 2010). Until now, there is no information concerning the use of the Moura breed in crosses with the aim of improving the amount of fat.

Throughout the life of a pig, its tissues grow in different proportions, which result in changes in corporal composition (DANFAER and STRATHE, 2012). Environmental limitations notwithstanding, the tissue growth depends on genetic factors (WISEMAN et al., 2007) and determines the nutritional need for growth (DANFAER and STRATHE, 2012). Thus, the growth curves allow one to identify the moment in which higher deposition of muscle, fat, skin, bones and viscera occur.

The aim of this study was to evaluate the tissue growth of crossbred pigs comprised of 29.7% Duroc, 15.6% Pietrain, 17.2% Large White, 25% Landrace, and 12.5% Moura genetic composition, and slaughtered at 22, 35, 60, 80, 100, 115 and 130 kg of live weight.

2.2. Materials and methods

The protocol for this experiment was approved by the Committee of Ethics on Animal Use for Research of Embrapa Swine and Poultry (protocol n. 007/2010). The experiment was carried out in 2013 in the facilities of the Brazilian Agricultural Research Corporation, in Concórdia, Santa Catarina. 28 barrows and 28 gilts were used, sired by 59.4% Duroc, 31.2% Pietrain and 9.4% Large White sires farrowed by 50% Landrace, 25% Large White and 25% Moura sows slaughtered at 22, 33, 60, 80, 100, 115 and 130 kg of live weight. The genetic lines came from the Embrapa swine breeding project and the experimental pigs belonged to the crossbreeding scheme designed to improve meat quality by the inclusion of the Moura breed. Animals were housed according to sex, with 4 pigs per pen. Four barrows and four gilts were used for each slaughter weight, in a total of 56 pigs. Diets were formulated to meet or exceed the nutritional requirements of National Research Council (NRC, 2012), according to live weight ranges (Table 8) and were fed *ad libitum* in semi-automated feeders.

All animals were submitted to the same management. The offered feed and the pigs were weighed weekly. In the early morning of the day of slaughter, following 12 hours of feed fasting, pigs were transported in a truck with a bed specifically designed for this purpose and slaughtered after three hours of lairage in the slaughterhouse located approximately 15 km from the farm. The slaughter weight means were as follows: 20.89 ± 1.46 kg, 37.7 ± 2.09 kg, 62.07 ± 2.53 kg, 81.96 ± 5.42 kg, 105.15 ± 1.25 kg, 113.47 ± 5.69 kg and 130.77 ± 9.18 kg for the slaughter weights of 22, 35, 60, 80, 100, 115 and 130 kg, respectively.

TABLE 8 - MAIN INGREDIENTS AND EXPECTED DIET NUTRITIONAL VALUES FED TO THE PIGS AS A FUNCTION OF LIVE WEIGHT RANGE.

Item	Live weight range, kg			
	22 – 60	60 - 80	80 - 115	115 - 130
Ingredients, %				
Corn	71.10	74.48	77.86	82.27
Soybean meal	23.50	21.06	18.13	14.26
Soybean oil	1.61	1.07	0.85	0.60
Dicalcium phosphate	1.27	1.11	0.99	0.81
Limestone	1.05	0.82	0.75	0.72
Salt	0.29	0.30	0.30	0.31
Amino acids*	0.34	0.37	0.34	0.25
Other**	0.84	0.78	0.78	0.78
Expected levels				
Crude protein, %	17	15.8	14.69	13.18
Metabolizable energy, kcal/kg	3260	3260	3260	3260
Calcium, %	0.7	0.62	0.56	0.5
Total phosphorus, %	0.53	0.51	0.48	0.44
Available phosphorus, %	0.35	0.31	0.28	0.24
Crude fiber, %	3.78	2.58	2.46	2.3
Lysine, %	1.07	0.99	0.9	0.77

*: L-lysine, L-threonine, L-tryptophan, DL-methionine; ** vitamin, trace mineral, and choline sulfate premix

Four pigs of each sex were slaughtered in the beginning of the experiment (22 kg) and the others were kept until reaching the target slaughter weight. The pigs were stunned by electronarcosis and the slaughter was performed by bleeding the pigs in the horizontal position following the standard procedures of the slaughterhouse. After that, pigs were eviscerated and the organs were split into heart, liver, kidneys, pancreas, stomach, bladder and gut. The liquids and other contents eventually present in stomach, bladder and gut were removed by compression and all viscera were weighed.

Carcasses were stored in a chilling room at 2 to 4 °C for 24 hours. The head and feet were removed and the carcasses were split into ham, shoulder, loin and belly+ribs. Following that division, cuts were further dissected into muscle (including intramuscular fat), extra muscular fat, skin, bones and others. The other fraction included feet, tail, glands, fascia, blood vessels, nerves and other unidentified structures.

In the beginning of the experiment, eight animals (four per sex) were slaughtered at 22 kg and each tissue and viscera were separated and weighed and a linear regression was performed between the pigs' weight and each tissue/viscera weight. For pigs slaughtered at 35, 60, 80, 100, 115 and 130 kg, the weight of each tissue/viscera in the beginning of the experiment were estimated according to the obtained regression. The percentages of each component were obtained relative to the empty body weight, calculated according to Wiseman et al. (2007). The daily gain of each tissue was calculated according to the following formula:

$$\frac{(amount\ of\ tissue\ at\ the\ slaugther\ - estimated\ amount\ of\ tissue\ in\ the\ \text{beginning of the experiment})}{days\ in\ experiment}$$

To describe the relationship between weight and age, muscle daily gain, fat daily gain, bone daily gain, viscera gain and lean/fat gain, the Michalis Menten equation was used: $age^n/(age^n+k)$. The parameters n and k were estimated by Statgraphics software (STATPOINT, 2005). The higher value obtained for each variable was considered as maximum value (1) and the others values classified proportionally.

For average daily fed intake, average daily weight gain, muscle daily gain and fat daily gain a polynomial analysis was performed according to the slaughter weight and terms of first, second and third order were tested. The model that showed the higher significant term was chosen for description.

2.3. Results and discussion

The relationship between age and weight is shown in Figure 4. Once the animals were kept in an environment without limitations (termoneutral, free of infectious agents, nutritional requirements suppled and free access to water and food), the growth curves showed the growth potential of the evaluated crossbreed (DANFAER *and* STRATHE, 2012).

The average daily weight gain showed a quadratic response ($P<0.05$, Table 9) with maximum point at 96.0 and 98.8 kg (0.960 and 0.895 kg/day) in barrows and gilts, respectively. Although the maximum point of average daily feed intake was at 117.6 and 120.0 kg in barrows and gilts, after reach 105 kg a trend of constant consumption was observed (Figure 5). After this weight, a decrease in the average daily weight gain was observed due to the reduction of consumption above the maintenance weight and the fat accumulation in the carcass (Table 11). To accumulate 1 g of fat, seven times more energy is needed than to accumulate lean (LEWIS and SOUTHERN, 2001).

FIGURE 4 - RELATIONSHIP BETWEEN AGE AND WEIGHT RELATIVE TO THE MAXIMUM GROWTH RATES IN BARROWS AND GILTS BETWEEN 22 AND 130 KG OF LIVE WEIGHT, ACCORDING TO THE MICHALIS MENTEN EQUATION: AGE^N/(AGE^N+K).

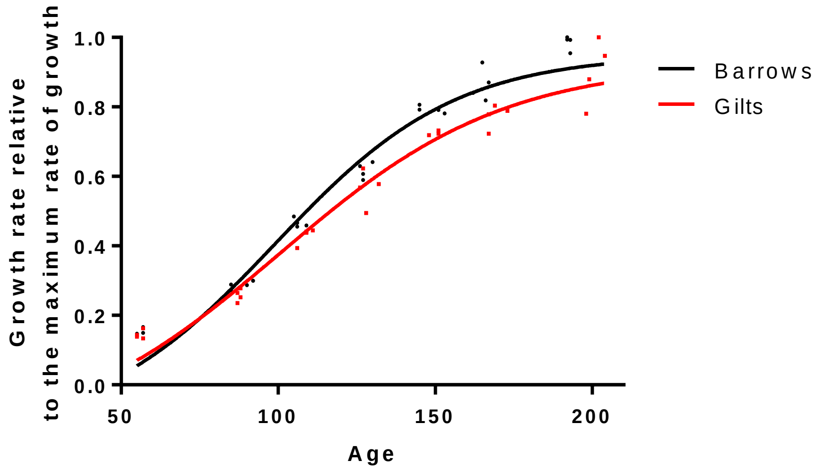
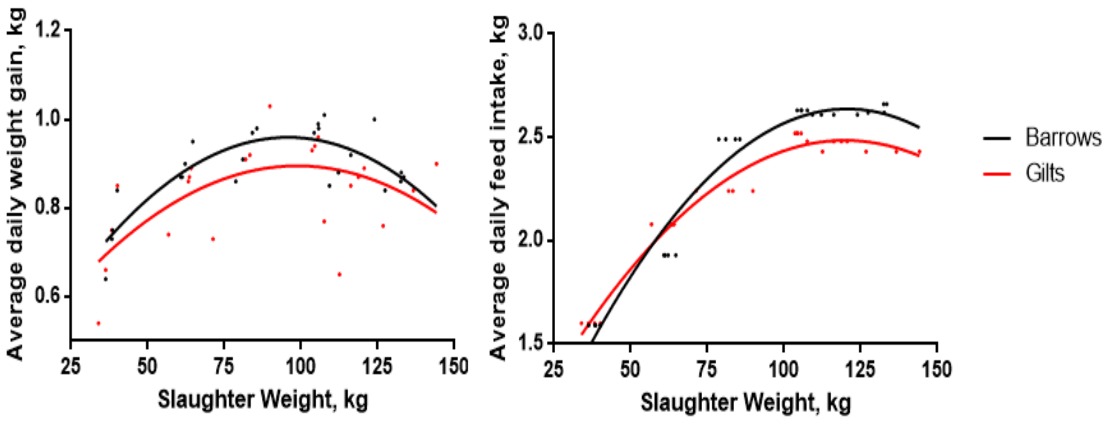


FIGURE 5 - AVERAGE DAILY WEIGHT GAIN AND AVERAGE DAILY FED INTAKE IN BARROWS AND GILTS BETWEEN 22 AND 130 KG OF LIVE WEIGHT.



The genotypes and breeds allocated to lean production have the maximum point of weight gain in lowers weights, which suggest that the evaluated crossbreed is later. Hamilton et al. (2003) reported an increase in weight gain until 80 kg and, after that, a constant value until 120 kg in two genetic lines intended for lean. In this evaluated range, the authors reported an average daily weight gain of 0.961 and 0.919 for barrows and gilts. Although these weight gains were similar to the values observed in the present study, there are differences in the proportion of deposition of each tissue (SCHINCKEL et al., 2014), which may due to the differences in genotype, sex, slaughter weight, nutrient supply and climatic factors (NOBLET et al., 1999).

TABLE 9 - PARAMETERS OF THE REGRESSION ANALYSIS OF LIVE PERFORMANCE OF BARROWS AND GILTS BETWEEN 22 AND 130 KG OF LIVE WEIGHT.

Dependent variable	Sex	Intercept	Coeficiente			P value			R^2
			Linear	Quadratic	Cubic	Linear	Quadratic	Cubic	
ADFI	B	1.076	0.005	0.000253	-0.000002	0.71	0.19	0.04	96.85
ADFI	G	0.656	0.030	-0.000127	-	<0.001	<0.001	0.88	97.01
ADWG	B	0.349	0.013	-0.000067	-	<0.001	<0.001	0.75	69.08
ADWG	G	0.393	0.010	-0.000051	-	0.01	0.02	0.16	36.69
MDG	B	152.484	4.518	-0.022697	-	0.00	0.01	0.62	48.18
MDG	G	260.603	3.403	-0.019309	-	0.03	0.03	0.05	19.90
FDG	B	-309.712	14.827	-0.145520	0.000506	0.00	0.02	0.04	89.26
FDG	G	11.641	1.591	-	-	<0.001	0.59	0.52	65.49

B=Barrows; G=Gilts; ADFI=Average daily feed intake; ADWG=Average daily weight gain; MDG=Muscle daily gain; FDG=Fat daily gain; SE=Standard error

Lean and fat deposition are the main variables that impact the effectiveness of the energy utilization in growing pigs. The lack of energy may be responsible for a decrease in the point of maximum protein deposition (LEWIS *and* SOUTHERN, 2001). In the present study, once the energy requirement was supplied, the results show the real potential for lean deposition in the evaluated crossbreed. The muscle daily gain showed quadratic behavior ($P<0.05$) in both sexes and reached the maximum point at 99.6 kg (149 days) and 88.2 kg (140 days): estimated values of 377.3 and 410.6 g/day for barrows and gilts, respectively (Figure 6). Considering the whole period, the muscle daily gain was 351.6±8.6 g/day for barrows and 390.2±9.0 g/day for gilts.

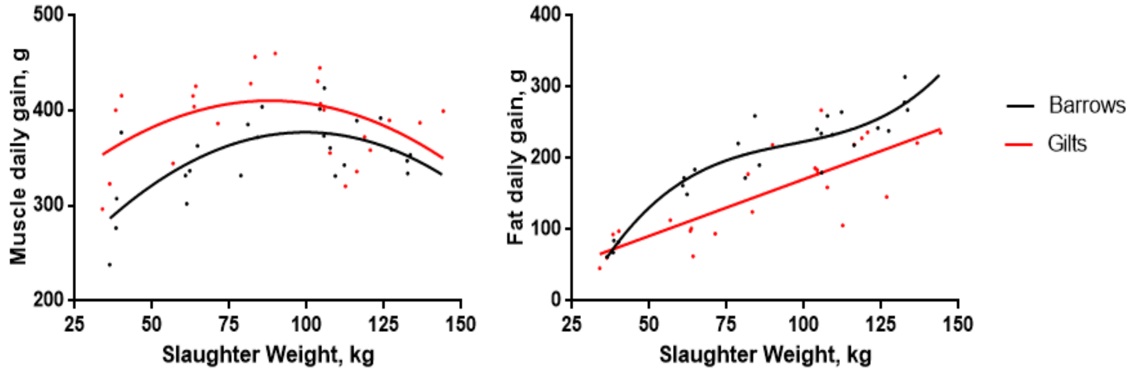
As observed in average daily gain, the rate of muscle deposition suggests that pigs from the evaluated crossbreed are later, since the point of maximum deposition is usually between 60 and 80 kg (DANFAER *and* STRATHE, 2012; VAN MILGEN *and* NOBLET, 2003; HAMILTON et al., 2003; SCHINCKEL et al., 1996). The later growth may be due to the introduction of the Moura breed, which has slower growth than breeds or lines intended for lean production.

In the present study, the muscle daily gain was obtained by dissection, which does not take into account the protein gain of the viscera, head and the tail. In addition, the intramuscular fat is not separated from muscles. However, it is accepted that the dissection method is more reliable than other methods (QUINIOU et al., 1995) and the difference between this method and the nitrogen balance technique varies between 2.9 and 9.5% (GARCÍA-VALVERDE et al., 2008; QUINIOU et al., 1995).

Using the same methodology, DANFAER *and* STRATHE (2012) studied Danish pigs intended for lean production. The authors related higher muscle daily gain, with maximum point in younger ages: 532 and 515 g/day in barrows and gilts at 120 and 115 days of age, respectively. Using different methodologies, Fix et al. (2010) reported that in the 1980s the protein daily gain was 227 g/day, while in 2005 grew to 306 g/day. Schinckel et al. (2008) studied genetics intended for lean and fat production and the protein daily gain was estimated in 375 and 280 g/day, respectively. In Italian heavy pigs, Bosi et al. (1999) estimated the protein daily gain in 295 g/day and Prandini et al. (1996) related 91.1 and 99.9 g/day at 80 and 160 kg of live weight.

Higher muscle gain rates are expected in breeds and lines intended for lean production (SCHINCKEL et al., 2008). In the evaluated crossbreed – although later - the muscle daily gain showed similar values to genetics intended for lean production, which may be attributed to the use of Pietrain and Landrace in the crossbred.

FIGURE 6 - MUSCLE DAILY GAIN AND FAT DAILY GAIN OF BARROWS AND GILTS SLAUGHTERED BETWEEN 22 AND 130 KG.



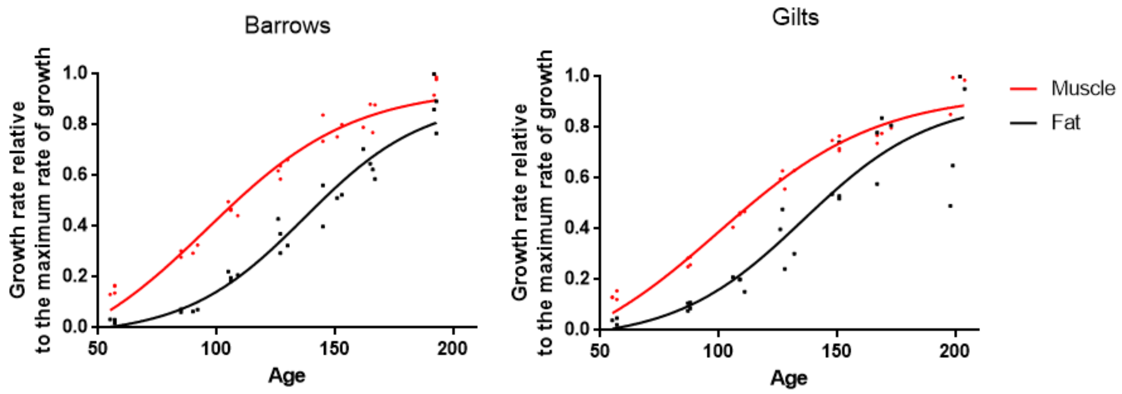
The inflection point of the muscle accumulation in barrows and gilts was at 150 days (Figure 7). From a biological standpoint, it is expected that the protein mass shows a sigmoidal shape, being the age of maximum accumulation dependent on each genetic. After reaching the point of maximum muscle accumulation, there is an increase in the energy fraction that is used for the fat accumulation (VAN MILGEN *and* NOBLET, 2003), which in turn increases the percentage of carcass fatness (SCHINCKEL et al., 2008).

The fat daily gain increased linearly in gilts and cubically in barrows with the slaughter weight and the higher gains were observed at 130 kg (Figure 6), with estimated values of 269.5 and 218.4 g/day for barrows and gilts, respectively. In the evaluated weight range, it was not possible obtain the point of maximum fat deposition, which usually occurs above 130 kg (VAN MILGEN *and* NOBLET, 2003).

In barrows, between 75 and 125 kg the fat daily gain was almost constant. After 125 kg, a sharp increase in fat daily gain was observed. In gilts, the fat daily gain increased linearly ($P<0.001$); however, with lower values and high variability in the data. Considering all slaughter weights, the fat daily gain mean in barrows was 30.7% greater than gilts (199.2 and 152.4 g/day, respectively). At 35 kg, barrows showed similar fat gain to the gilts (Figure 6). After 60 kg this difference increased and, at 130 kg, barrows showed a daily fat gain 64.5% greater than gilts. The higher content of fat in barrows is well documented in the literature (OLIVEIRA et al., 2015; SCHINCKEL et al., 2008) and is due to the high feed intake after 80 kg.

From 170 days, high variability in amount of fat in gilts carcasses was observed (Figure 7). This variability has negative consequences for the consumer market, which has a preference for uniform products and of similar weight (DANFAER *and* STRATHE, 2012). The observed variability may be due to the introduction of Moura breed, which was not submitted to any genetic selection. The increase in fat accumulation with the increase in slaughter weight is expected in the absence of feed restriction. However, in genetics with low potential for lean gain, the fat gain is higher. Schinckel et al. (2008) reported that the fat deposition in genetics of high potential of lean deposition was 37% less than in genetics of low potential of fat deposition at 130 kg.

FIGURE 7 - MUSCLE AND FAT ACCUMULATION ACCORDING TO THE AGE RELATIVE TO THE MAXIMUM GROWTH RATES IN BARROWS AND GILTS BETWEEN 22 AND 130 KG OF LIVE WEIGHT, ACCORDING TO THE MICHALIS MENTEN EQUATION: $AGE^N/(AGE^N+K)$.



Although the percentage of muscle in carcasses were almost constant, the fat percentage rose with the increase in slaughter weight. Without considering the effect of sex, the mean of fat in carcass was 13.19±1.1, 19.91±1.1, 25.65±1.0 and 30.92±2.9 kg at 80, 100, 115 e 130 kg. Similar values are reported by Rizzi (2006): 16.0, 31.2 and 49.4 at 80, 120 and 170 kg in Italian heavy pigs, which shows the ability of the evaluated crossbreed in depositing fat. Thus, if the aim is to produce carcasses with high levels of extra muscular fat, it is recommended that the slaughter be performed after 130 kg.

The selection for lean production may be responsible for worsening in pork quality (SCHWAB et al., 2006; LONERGAN et al., 2001). Higher levels of fat are related to the production of dry cured products of higher quality. The amount of fat in carcass increases the water retention capacity (CANDEK-POTOKAR et al., 2002) and the lipolysis releases compounds responsible for the characteristic flavor of cured products (FLORES et al., 1997; BOLZONI et al., 1996). Moreover, the intramuscular fat may favor the pork *in natura* commerce, since it is related to such attributes as juiciness (FERNANDEZ et al., 1999a) and softness (TEYE et al., 2006).

In the present study, the introduction of Duroc and Moura breeds may be responsible for de high fat gain. As in Duroc, the use of Moura breed in crosses increases the backfat thickness in carcass (Bertol et al., 2010; Fávero et al., 2007). Other studies also indicate that the use of local breeds, preserved by small farmers and not subjected to genetic selections, are later than lean breeds and has higher capacity of fat accumulation: in Italy (FRANCI et al., 2003), France (LEBRET et al., 2014), Spain (LOPEZ-BOTE, 1998), Czech republic (DOSTÁLOVÁ et al., 2012), China (JIANG et al., 2012) and Germany (SCHWALM et al., 2013).

TABLE 10 - PARAMETERS ESTIMATED BY MICHALIS MENTEN EQUATION (AGE^N/(AGE^N+K)) FOR TISSUES GROWTHS FOR BARROWS AND GILTS BETWEEN 22 AND 130 KG.

Variable	n		k		R^2	
	Barrows	Gilts	Barrows	Gilts	Barrows	Gilts
Final weight	4.090	3.408	212203000	10909700	96.46	96.48
Muscle	3.788	3.573	50584600	21969300	96.485	96.83
Fat	4.998	4.739	61663100000	16260600000	95.76	87.44
Muscle/fat	-2.741	-1.729	0.000004411	0.000450405	85.60	76.13
Bone	3.195	2.958	2092900	971288	93.56	93.88
Skin	2.995	2.812	1111390	474458	92.450	94.65
Head	2.754	2.239	367142	3874820	93.76	88.87
Total viscera	2.527	2.172	87825	22536	95.09	92.83
Heart	2.73319	2.68885	298506	244606	88.39	94.94
Liver	2.70957	2.20967	191707	24738	87.45	86.09
Kidney	2.15028	2.67132	17439	140788	86.83	88.79
Pancreas	2.09129	2.32052	23101	92603	72.73	82.54
Stomach	2.64415	2.80558	156571	307591	87.84	92.17
Bladder	2.24611	3.10437	62076	2783890	65.37	86.59
Gut	2.30988	1.97991	34676	10358	93.81	88.00

FIGURE 8 - BONES, SKIN AND VISCERA ACCUMULATION ACCORDING TO THE AGE RELATIVE TO THE MAXIMUM GROWTH RATES IN BARROWS AND GILTS BETWEEN 22 AND 130 KG OF LIVE WEIGHT, ACCORDING TO THE MICHALIS MENTEN EQUATION: AGE^{N}/(AGE^{N}+K).

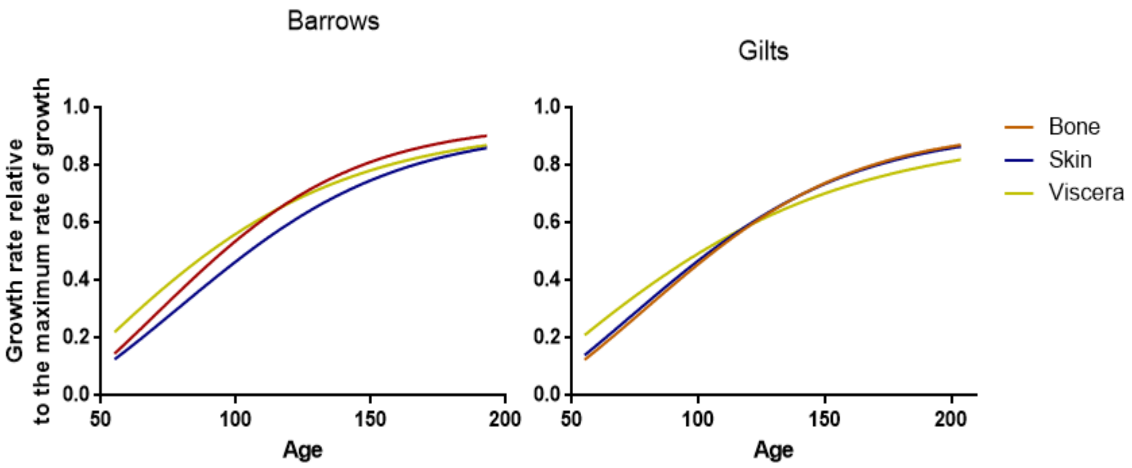
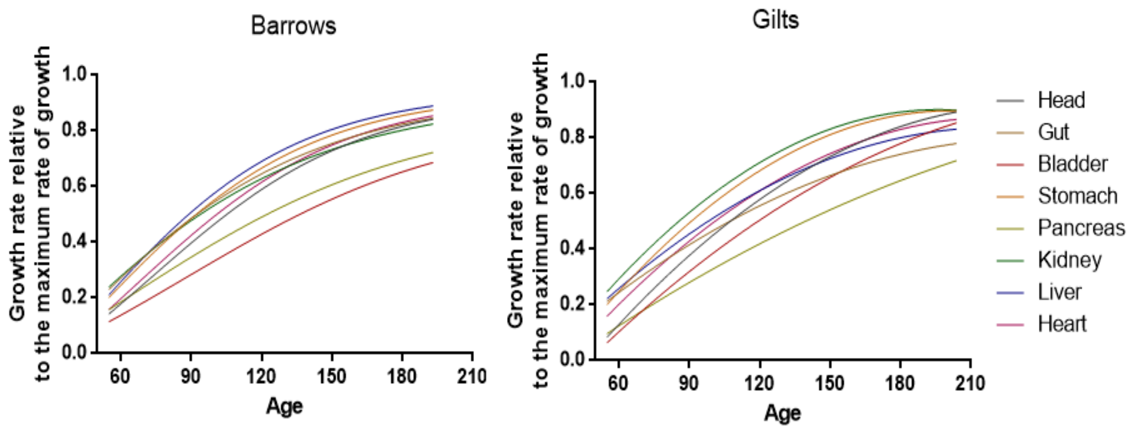


FIGURE 9 - HEART, LIVER, KIDNEY, PANCREAS, STOMACH, BLADDER AND GUT ACCUMULATION ACCORDING TO THE AGE RELATIVE TO THE MAXIMUM GROWTH RATES IN BARROWS AND GILTS BETWEEN 22 AND 130 KG OF LIVE WEIGHT, ACCORDING TO THE MICHALIS MENTEN EQUATION: AGE^{N}/(AGE^{N}+K).



The growth of muscle and bones showed similar behavior (Figure 7 and 9). The growth of bones and muscles are strongly interconnected (LAWRENCE *and* FOWLER, 2002) due to the function of bones to support the muscle. Knowledge about the viscera weight is essential to obtaining the carcass yield and to estimating the requirements for maintenance, since the viscera contributes three times more than muscle to these requirements (NOBLET et al., 1999). With aging, the carcass growth is higher than viscera growth, which increases the carcass yield (GU et al., 1992) due to the decrease in the viscera proportion (LEWIS and SOUTHERN, 2001). This effect was observed in the present study: although the viscera weight increased, the proportion of viscera decreased according to the aging (Table 11). Other studies have shown that later and non-selected breeds have less viscera weight and therefore a higher carcass yield (LEBRET et al., 2014, RENAUDEAU and MOUROT, 2007).

In barrows and gilts, the aggregate growth of heart, liver, kidney, stomach, head and gut showed similar behavior, with a strong increase until 150 days of age. On the other hand, the bladder and pancreas showed a tendency towards a linear increase (Figure 9). These results show that viscera bear similar behavior to muscle and different behavior to fat: viscera have high priority of growth in the early stages (0-150 days) and the fat increases with high intensity in the later stages (after 140 days).

Gut is the viscera that has higher weight and proportion, due to its function of absorbing nutrients, and thus is greater in size. In the present study, although an increase in gut weight was observed according to the aging, gut percentage according to the empty body weight remained constant (Table 12).

TABLE 11 - MEANS AND STANDARD ERRORS FOR PERFORMANCE, TISSUES GAIN AND TISSUES COMPOSITION OF BARROWS AND GILTS SLAUGHTERED BETWEEN 22 AND 130 KG OF LIVE WEIGHT.

Variable	Target slaughter weight, kg													
	22		35		60		80		100		115		130	
	B	G	B	G	B	G	B	G	B	G	B	G	B	G
Final weight, kg	20.87±0.6	20.9±0.9	38.27±0.8	37.12±1.3	62.22±0.9	61.92±1.7	82.35±1.5	81.57±3.8	105.8±0.7	104.5±0.4	115.4±3.2	111.5±2.5	131.52±1.4	130.02±6.8
Final age, kg	56.5±0.5	56.0±0.6	88.0±1.8	87.5±0.3	106.5±0.9	108.75±1.0	127.5±0.9	128.25±1.3	148.5±2.1	150.25±0.7	165.0±1.1	169.0±1.4	192.5±0.3	200.75±1.4
ADFI, kg	-	-	1.588	1.601	1.927	2.077	2.487	2.236	2.63	2.518	2.614	2.48	2.622	2.429
ADWG, kg	-	-	0.74±0.04	0.70±0.07	0.90±0.02	0.84±0.03	0.93±0.03	0.90±0.06	0.99±0.01	0.94±0.006	0.91±0.03	0.84±0.03	0.86±0.02	0.79±0.05
EIAM, day	-	-	3007.2	3089.0	3377.8	3875.2	4671.4	3872.7	4580.2	4244.6	4314.4	3963.4	3997.1	3399.1
MDG, g	-	-	299.9±29.4	359.15±29.1	333.51±12.5	397.56±18.2	373.41±15.3	433.08±17.0	390.13±14.2	421.14±10.2	364.11±15.7	355.69±7.5	348.52±5.3	374.39±18.1
FDG,g	-	-	74.01±5.6	74.31±12.6	167.00±7.4	93.83±10.9	210.84±19.0	153.97±27.7	228.77±17.1	204.32±21.1	239.72±9.7	210.72±17.5	274.76±15.6	177.22±30.9
BDG, g	-	-	68.95±1.6	62.79±7.7	62.92±3.2	79.62±6.0	62.96±4.8	71.18±6.4	69.11±1.8	63.87±1.5	58.47±3.0	60.29±3.0	56.73±0.6	62.53±1.5
SDG, g	-	-	26.30±2.6	30.71±1.0	28.90±1.4	28.65±2.9	20.71±1.0	24.59±2.0	24.86±1.1	23.57±0.9	24.79±1.9	21.02±1.4	21.75±0.9	20.66±0.9
VDG, g	-	-	54.41±10.3	55.91±7.1	59.41±2.9	54.98±5.6	51.18±2.5	48.46±2.8	46.40±1.2	40.59±3.5	41.76±1.7	35.73±1.2	39.4±2.6	38.38±2.8
Muscle, kg	8.36±0.5	8.52±0.47	16.76±0.6	17.20±0.6	26.08±0.6	28.53±0.9	34.92±0.9	38.33±1.1	43.61±1.3	46.72±0.9	46.31±1.6	48.96±0.8	54.16±1.0	60.93±2.3
Muscle, %[1]	49.62±1.1	50.34±0.5	53.90±0.4	54.36±0.6	49.81±0.5	54.08±0.5	49.58±1.0	53.92±1.2	48.80±1.4	52.18±1.3	46.79±1.1	47.99±1.4	45.10±1.1	51.53±1.4
Fat, kg	1.11±0.13	1.21±0.19	2.76±0.11	3.18±0.27	8.3±0.32	6.35±0.44	14.54±1.2	11.83±1.7	20.44±1.4	19.39±1.8	26.26±1.0	25.03±2.0	36.07±2.0	25.77±4.1
Fat, %[1]	6.59±0.84	7.05±0.89	8.88±0.19	10.00±0.49	15.85±0.5	12.12±1.0	20.63±1.6	16.4±1.8	22.86±1.6	21.59±1.7	26.57±1.1	24.38±1.3	29.98±1.4	21.36±2.4
Bones, kg	2.36±0.06	2.32±0.05	4.01±0.04	3.71±0.16	5.36±0.14	5.87±0.26	6.62±0.30	6.96±0.40	8.40±0.16	7.86±0.12	8.47±0.31	9.11±0.34	9.71±0.06	10.84±0.2
Bones, %[1]	14.07±0.3	13.77±0.5	12.94±0.4	11.74±0.5	10.25±0.3	11.11±0.2	9.4±0.42	9.77±0.36	9.40±0.18	8.77±0.16	8.56±0.19	8.92±0.31	8.08±0.05	9.22±0.55
Skin, kg	0.76±0.03	0.74±0.05	1.39±0.06	1.41±0.02	2.11±0.06	2.03±0.12	2.18±0.06	2.35±0.13	2.94±0.09	2.79±0.07	3.35±0.20	3.11±0.16	3.58±0.13	3.56±0.11
Skin, %[1]	4.53±0.18	4.42±0.35	4.47±0.16	4.48±0.12	4.03±0.06	3.83±0.16	3.09±0.06	3.29±0.05	3.29±0.12	3.11±0.08	3.38±0.14	3.04±0.10	2.98±0.11	3.02±0.09
Viscera, kg	2.14±0.05	2.07±0.05	3.47±0.21	3.34±0.15	4.96±0.12	4.67±0.24	5.62±0.17	5.35±0.18	6.25±0.10	5.73±0.30	6.50±0.17	6.12±0.13	7.23±0.31	7.41±0.36
Viscera, %[1]	12.76±0.3	12.29±0.3	11.14±0.4	10.57±0.36	9.50±0.33	8.86±0.42	8.00±0.26	7.51±0.17	7.00±0.15	6.41±0.40	6.57±0.12	6.00±0.13	6.02±0.23	6.26±0.21
Head, kg	1.52±0.06	1.5±0.04	2.52±0.06	2.67±0.19	4.12±0.07	3.87±0.19	4.92±0.38	4.72±0.36	5.55±0.09	5.13±0.08	5.9±0.22	7.6±0.27	6.87±0.32	7.47±0.23
Head, %[1]	9.08±0.23	8.91±0.30	8.14±0.27	8.43±0.36	7.88±0.15	7.35±0.29	6.97±0.41	6.62±0.39	6.21±0.09	5.73±0.11	5.97±0.23	7.44±0.13	5.73±0.33	6.37±0.48
Others, kg	2.06±0.08	2.01±0.04	2.64±0.07	2.77±0.16	5.47±0.05	5.21±0.22	6.50±0.42	6.40±0.42	7.57±0.07	6.97±0.11	7.89±0.20	9.65±0.37	9.20±0.34	9.87±0.26
Others, %[1]	12.29±0.3	11.96±0.3	8.54±0.28	8.75±0.25	10.47±0.1	9.89±0.24	9.21±0.43	8.99±0.43	8.49±0.10	7.80±0.18	7.99±0.17	9.45±0.17	7.68±0.37	8.44±0.64

[1]=Percentage according to the empty body weight; B=Barrows; G=Gilts; ADFI=Average daily feed intake; ADWG=Average daily weight gain; EIAM=Energy intake above maintence (243,6kcal/kg^{0,60} metabolic weight, according to Noblet et al., 1999); MDG=Muscle daily gain in carcass; FDG=Fat daily gain in carcass; BDG=Bone daily gain in carcass; SDG=Skin daily gain in carcass; VDG=Viscera daily gain in carcass; Others= feet, tail, glands, fascia, blood vessels, nerves and other unidentified structures.

TABLE 12 - MEANS AND STANDARD ERRORS FOR WEIGHT AND PERCENTAGE OF VISCERA FROM BARROWS AND GILTS SLAUGHTERED BETWEEN 22 AND 130 KG OF LIVE WEIGHT.

Variable	Target slaughter weight, kg.													
	22		35		60		80		100		115		130	
	B	G	B	G	B	G	B	G	B	G	B	G	B	G
Heart, kg	0.10±0.003	0.10±0.003	0.17±0.005	0.17±0.007	0.24±0.006	0.24±0.01	0.28±0.04	0.27±0.006	0.33±0.01	0.32±0.005	0.35±0.01	0.37±0.005	0.43±0.01	0.41±0.02
Heart, %[1]	0.61±0.02	0.61±0.01	0.55±0.01	0.53±0.009	0.46±0.01	0.45±0.01	0.40±0.05	0.39±0.01	0.37±0.02	0.36±0.006	0.35±0.007	0.36±0.01	0.36±0.01	0.35±0.02
Liver, kg	0.42±0.04	0.45±0.03	0.73±0.07	0.74±0.05	1.23±0.04	1.07±0.07	1.27±0.06	1.27±0.05	1.41±0.04	1.18±0.11	1.29±0.08	1.48±0.05	1.64±0.05	1.54±0.10
Liver, %[1]	2.48±0.24	2.66±0.17	2.35±0.17	2.34±0.12	2.35±0.11	2.03±0.11	1.80±0.11	1.79±0.08	1.58±0.05	1.32±0.14	1.31±0.07	1.45±0.08	1.37±0.03	1.30±0.08
Kidney, kg	0.12±0.01	0.11±0.007	0.18±0.02	0.18±0.01	0.26±0.02	0.25±0.02	0.27±0.003	0.31±0.01	0.30±0.007	0.30±0.02	0.34±0.02	0.35±0.01	0.36±0.02	0.35±0.01
Kidney, %[1]	0.72±0.06	0.66±0.02	0.56±0.04	0.59±0.04	0.49±0.03	0.47±0.04	0.39±0.006	0.44±0.01	0.33±0.007	0.34±0.02	0.34±0.01	0.35±0.02	0.30±0.02	0.30±0.009
Pancreas, kg	0.06±0.009	0.05±0.006	0.07±0.01	0.07±0.004	0.09±0.002	0.11±0.01	0.12±0.007	0.12±0.006	0.13±0.01	0.15±0.007	0.16±0.02	0.19±0.01	0.19±0.02	0.22±0.03
Pancreas, %[1]	0.37±0.05	0.32±0.04	0.21±0.03	0.22±0.01	0.18±0.005	0.21±0.02	0.17±0.01	0.17±0.009	0.14±0.02	0.17±0.01	0.16±0.02	0.18±0.01	0.16±0.01	0.19±0.03
Stomach, kg	0.17±0.009	0.15±0.007	0.28±0.03	0.33±0.01	0.43±0.01	0.41±0.02	0.51±0.01	0.47±0.02	0.55±0.04	0.52±0.02	0.62±0.04	0.63±0.03	0.59±0.04	0.62±0.03
Stomach, %[1]	1.04±0.03	0.91±0.05	0.92±0.07	1.03±0.04	0.82±0.03	0.78±0.02	0.73±0.03	0.65±0.01	0.62±0.05	0.58±0.03	0.62±0.05	0.62±0.01	0.49±0.03	0.52±0.008
Bladder, kg	0.009±0.001	0.01±0.0004	0.01±0.001	0.02±0.0003	0.03±0.001	0.02±0.003	0.03±0.005	0.03±0.004	0.04±0.002	0.04±0.004	0.06±0.007	0.03±0.01	0.04±0.006	0.05±0.003
Bladder, %[1]	0.05±0.005	0.06±0.001	0.05±0.003	0.05±0.001	0.05±0.002	0.05±0.004	0.04±0.002	0.05±0.006	0.05±0.002	0.05±0.004	0.06±0.008	0.03±0.01	0.03±0.004	0.05±0.0004
Gut, kg	1.25±0.04	1.19±0.03	2.02±0.10	1.84±0.07	2.69±0.10	2.56±0.13	3.14±0.10	2.87±0.11	3.49±0.07	3.21±0.14	3.69±0.11	3.07±0.11	3.98±0.23	4.20±0.24
Gut, %[1]	7.48±0.35	7.01±0.28	6.50±0.25	5.81±0.19	5.15±0.24	4.87±0.27	4.46±0.15	4.03±0.06	3.91±0.10	3.59±0.20	3.72±0.03	3.00±0.07	3.31±0.17	3.55±0.09

[1]=Percentage according to the empty body weight; B=Barrows; G=Gil

2.4. Conclusions

The evaluated crossbreed showed characteristics of later breeds, reaching point of maximum muscle accumulation at 99.6 kg (barrows) and 88.2 kg (gilts) and high capacity for fat accumulation, mainly after 125 kg. However, the values of muscle gain are similar to breeds and genotypes intended for lean production. The increase in the amount of fat in older ages suggest that the evaluated crossbreed may be used for dry-cured or fermented products.

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CHAPTER 3 – NUTRITIONAL NEEDS OF MOURA CROSSBRED PIGS ESTIMATED BY INRAPORC®

Abstract

In accordance with pig production, most of the costs are associated with feeding. In diet formulation, tables that overestimate amino acid needs are often used, leading to an increase in production costs. In this context, the software INRAPORC® is used as a tool to accurately estimate the nutritional needs in specific scenarios. The aim of this study was to estimate the amino acid needs of crossbred pigs with 29.7% Duroc, 15.6% Pietrain, 17.2% Large White, 25% Landrace and 12.5% Moura, weighing between 22 and 130 kg. To this aim, INRAPORC® was calibrated with a consumption data of 8 barrows and 16 gilts, with a diet calculated to meet or exceed the nutritional needs. An excess in all amino acids given was observed. The lysine need estimated by INRAPORC® increased until 70 kg in barrows and gilts: 16.30 and 15.13 g/day, respectively and, as consequence, the needs of other amino acids increased until this weight range. It was concluded that The amino acids needs estimated by INRAPORC® increased until 70 kg in barrows and gilts.

Keywords: heavy pigs, nutritional strategy.

3.1. Introduction

The expression of the genetic potential in pigs depends on an environment free of restrictions: thermoneutral, free of infectious agents, *ad libitum* water and food access and nutritional needs supplied (Danfaer and Strathe, 2012). Among such items, feed costs are of high relevance, once they may represent more than 60% of the production costs (Pomar et al., 2009).

The methods commonly used by the industry to estimate the nutritional needs are tables which, despite being functional, provide generalization for specific scenarios (Fraga et al., 2015). In order to avoid any deficiency in nutrient supply and, consequently, a decrease in performance, these tables often overestimate nutritional needs. In addition to an increase in the production costs (Rossi et al., 2013; Pomar et al., 2009), the excess of nutrients may cause high levels of nutrients being release in the environment (Lovato, 2014; Pomar et al., 2009).

INRAPORC® is a system that integrates information about growing pigs and sows and may be used as a decision support tool for end-users (van Milgen et al., 2008). The purpose of INRAPORC® is to analyze the use of nutrients in specific pig types and to evaluate the effect of different nutritional programs in terms of nutrient use, performance and carcass characteristics (van Milgen et al., 2008). Thus, the software makes it possible to simulate events for each specific scenario (Fraga et al., 2015). The system is based on the transformation of nutrients in lipids and proteins in order to estimate live weight, lean and backfat thickness (van Milgen et al., 2008). INRAPORC® has been successfully used to reduce production costs Monteiro, 2014; Rossi et al., 2013; Pomar et al., 2009), to predict nutrients excretion (Monteiro, 2014; Pomar et al., 2009; van Milgen et al., 2008) and to estimate nutritional needs as well as to develop nutritional strategies (Siqueira, 2016; Lovato, 2014 Quiniou et al., 2009).

In this context, the aim of this study was to estimate the amino acid needs of crossbred pigs with 29.7% Duroc, 15.6% Pietrain, 17.2% Large White, 25% Landrace, and 12.5% Moura, weighing between 22 and 130 kg.

3.2. Material and Methods

This experiment protocol was approved by the Ethics on Animal Use for Research Committee, Embrapa Swine and Poultry (protocol n. 007/2010). The experiment was conducted in 2013 in the facilities of the Brazilian Agricultural Research Corporation, in the city of Concórdia, Santa Catarina, Brazil. 8 barrows and 16 gilts, sired by 59.4% Duroc, 31.2% Pietrain and 9.4% Large White sires farrowed by 50% Landrace, 25% Large White and 25% Moura sows were evaluated, with initial weight of 23.12±0.34 kg and final weight of 128.84±1.31 kg. The genetic lines came from Embrapa Swine Breeding Project, and the experimental pigs belonged to the crossbreeding scheme designed to improve meat quality by the inclusion of the Moura breed.

Pigs were housed by sex, with 3-4 animals per pen. Diets were formulated to attend or exceed the nutritional requirements set by the National Research Council (NRC, 2012), according to live weight ranges (Table 13), and the animals were fed *ad libitum* in semi-automated feeders. Both the feed given and the pigs were weighed weekly. Before the transport to the slaughterhouse, backfat thickness at last rib was measured, using an ultrasound apparatus (ALOKA SSD-500V), coupled with a linear array transducer (UST 5011-3.5 MHz) and managed via BioSoft Toolbox® software for Swine from Biotronics Inc.

Diet composition, feed intake and animal performance for barrows and gilts were tabulated into INRAPORC® (INRAPORC®, 2010). To calibrate the software, it was estimated a diet loss of 5% up to 50 kg live weight. The equation that better adjusted to each sex were used: linear for barrows and Gompertz for gilts. The data obtained for the estimated needs underwent descriptive statistical analysis. According to the estimated needs, a feed management simulation was performed using INRAPORC®, divided into 4 phases according to sex and live weight: growth I (22 to 50 kg), growth II (50 to 75 kg), growth III (75 to 100 kg) and final (100 to 130 kg). The curves were adjusted as needed, by removing or adding the nutrients in excess or falling short.

TABLE 13 - MAIN INGREDIENTS AND EXPECTED DIET NUTRITIONAL VALUES FED TO THE PIGS AS A FUNCTION OF LIVE WEIGHT RANGE.

Item	Live weight range, kg			
	22 - 60	60 - 80	80 - 115	115 - 130
Ingredients, %				
Corn	71.10	74.48	77.86	82.27
Soybean meal	23.50	21.06	18.13	14.26
Soybean oil	1.61	1.07	0.85	0.60
Dicalcium phosphate	1.27	1.11	0.99	0.81
Limestone	1.05	0.82	0.75	0.72
Salt	0.29	0.30	0.30	0.31
Amino acids*	0.34	0.37	0.34	0.25
Other**	0.84	0.78	0.78	0.78
Expected levels				
Crude protein, %	17	15.8	14.69	13.18
Metabolizable energy, kcal/kg	3260	3260	3260	3260
Calcium, %	0.7	0.62	0.56	0.5
Total phosphorus, %	0.53	0.51	0.48	0.44
Available phosphorus, %	0.35	0.31	0.28	0.24
Crude fiber, %	3.78	2.58	2.46	2.3
Lysine, %	1.07	0.99	0.9	0.77

*: L-lysine, L-threonine, L-tryptophan, DL-methionine; ** vitamin, trace mineral, and choline sulfate premix

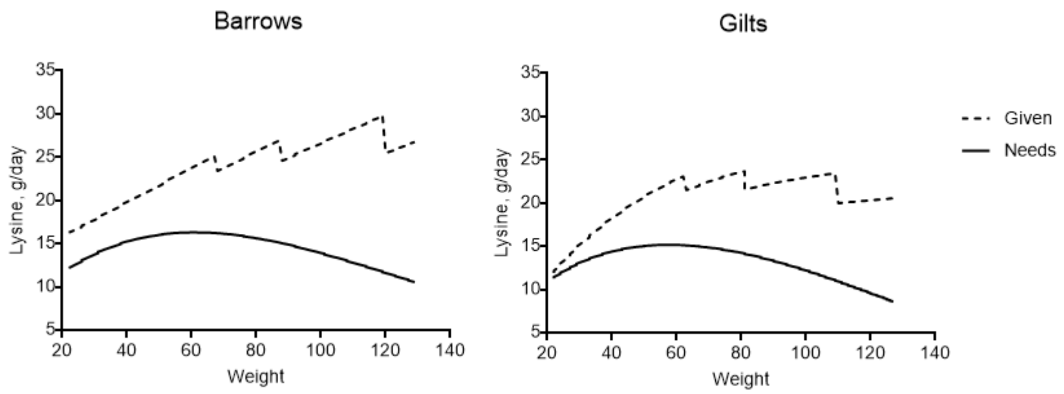
3.3. Results and Discussion

Amino acid needs for barrows and gilts are showed in Tables 14 and 15. The estimate of the amino acid needs usually takes into account the need of one animal. However, there are variations in needs between animals of the same population. Thus, in order to estimate the needs, it was considered the needs for the population, which are 10% higher than individual needs (Borssard et al., 2009). Backfat values, measured by ultrasound at the end of the experiment, were 25.7 mm and 22.7 mm for barrows and gilts, respectively. The estimated values after the calibration by INRAPORC® were 25.5 mm and 24.1 mm, which shows that the software was able to predict with high accuracy the fat deposition in the evaluated crossbreed.

INRAPORC® uses the ideal protein concept, wherein lysine is the reference for the other amino acids. The lysine need estimated by INRAPORC® increased until 70 kg in barrows and gilts: 16.30 and 15.13 g/day, respectively.

As consequence, the needs of other amino acids increased until this weight range. In this study, the average lysine daily needs were 14.3 and 12.9 g for barrows and gilts, respectively. With the experimental diet, it was offered an average of 24.0 g of lysine/day to barrows, an excess of 1164 g in total in the whole period. For gilts, the average daily lysine amount given was 20.5 g, an excess of 1036 g in total. This excess is expected once the diet was formulated to meet or exceed the nutritional needs and are presented on Figure 10.

FIGURE 10 - DIGESTIBLE LYSINE LEVELS GIVEN BY THE EXPERIMENTAL DIET AND POPULATION NEEDS ACCORDING TO INRAPORC® SIMULATION FOR BARROWS AND GILTS BETWEEN 22 AND 129 KG.



Amino acids are molecules that consist of a carboxyl group and an amino group bonded to the carbon atom. They differ from each other by the presence of side chains and are the constituents of proteins (Nelson and Cox, 2002). When given in excess, amino acids are catabolized and affect the kidneys and liver (Le Bellego and Noblet, 2002). In this process, where the resulting nitrogen from the protein degradation is excreted as urea, there is energy expenditure (Lewis and Southern, 2001), which decreases energy utilization efficiency. Therefore, in a diet with amino acids above the required levels, as observed in this study, energy use is less efficient than in a diet with appropriate levels of amino acids (Noblet et al., 2001).

Besides, the use of amino acids above the needs is responsible for an increase in feed costs (Rossi et al., 2013; Pomar et al., 2009), which may account for more than 60% of the production costs (Pomar et al., 2009) and for high levels of nitrogen excretion (Lovato, 2014; Pomar et al., 2009). According to Lovato

(2014), the use of models can reduce nitrogen excretion by 7.7 thousand tons per year in Brazil.

In this context, INRAPORC® is used as an accurate tool to estimate amino acid needs (Siqueira, 2016, Fraga et al., 2015; Quiniou et al., 2009) and as a decision support tool (van Milgen et al., 2008). Feed intake, energy levels and amino acids used in the simulated diet are shown in Tables 16 and 17, and the curves of lysine given and needed in the diet simulation are shown in Figure 11. The percentages of amino acid reduction using the simulated diet are shown in Table 18.

The diet divided into four phases and in same sex groups led to a more accurate adjustment of the population needs and a reduction in the use of amino acids. With the simulated diet, the use of lysine was reduced by 33% and 27.8% in barrows and gilts, respectively. This result was greater than the one observed by Lovato (2014), which reported a 12% reduction in the digestible lysine levels with the use of INRAPORC® under Brazilian commercial conditions. This adjustment may be responsible for reducing feed costs, mainly due to a reduced need of adding synthetic amino acids, increasing energy efficiency and reducing nitrogen excretion.

TABLE 14 - DIGESTIBLE AMINO ACID NEEDS ESTIMATED BY INRAPORC® FOR BARROWS BETWEEN 22 AND 129 KG LIVE WEIGHT.

Variable	Weight range, kg										
	22-30	30-40	40-50	50-60	60-70	70-80	80-90	90-100	100-110	110-120	120-129
Period, days	10	12	10	11	10	11	10	11	12	12	11
Age, days	67-76	76-88	88-98	98-109	109-119	119-130	130-140	140-151	151-163	163-175	175-186
Lysine, g/day	13.73	15.25	16.00	16.29	16.30	16.11	15.55	14.81	13.82	12.66	11.50
Methionine, g/day	4.15	4.61	4.83	4.92	4.92	4.86	4.68	4.45	4.15	3.80	3.44
Methionin+cystine, g/day [1,]	8.21	9.12	9.57	9.76	9.76	9.66	9.33	8.91	8.33	7.66	6.97
Cystine, g/day	4.06	4.51	4.74	4.84	4.84	4.80	4.65	4.45	4.18	3.86	3.54
Tryptophan, g/day	2.47	2.75	2.89	2.95	2.95	2.93	2.84	2.72	2.56	2.37	2.18
Threonine, g/day	8.85	9.82	10.32	10.53	10.53	10.44	10.11	9.66	9.07	8.37	7.66
Phenylalanine, g/day	6.82	7.58	7.97	8.14	8.15	8.09	7.85	7.53	7.09	6.57	6.05
Phenylalanine+tyrosine, g/day [1]	13.01	14.45	15.18	15.50	15.51	15.38	14.91	14.27	13.40	12.39	11.36
Tyrosine, g/day	6.19	6.88	7.22	7.36	7.36	7.29	7.05	6.74	6.31	5.81	5.31
Leucine, g/day	13.69	15.21	15.98	16.30	16.31	16.17	15.65	14.96	14.03	12.94	11.84
Isoleucine, g/day	7.49	8.32	8.74	8.91	8.92	8.83	8.55	8.17	7.65	7.05	6.45
Valine, g/day	9.61	10.68	11.22	11.45	11.46	11.36	11.01	10.53	9.89	9.13	8.37
Histidine, g/day	4.36	4.85	5.09	5.20	5.20	5.16	5.00	4.78	4.49	4.14	3.79
Arginine, g/day	5.87	6.50	6.81	6.92	6.92	6.84	6.62	6.32	5.91	5.37	4.92

[1] Amino acids are taken together due to the possibility of interconversion.

TABLE 15 - DIGESTIBLE AMINO ACID NEEDS ESTIMATED BY INRAPORC® FOR GILTS BETWEEN 22 AND 129 KG LIVE WEIGHT.

Variable	Weight range, kg										
	22-30	30-40	40-50	50-60	60-70	70-80	80-90	90-100	100-110	110-120	120-127
Period, days	13	12	12	11	11	11	12	13	14	15	12
Age, days	66-78	78-90	90-101	101-113	113-124	124-135	135-147	147-160	160-174	174-189	189-201
Lysine, g/day	13.11	14.38	15.04	15.16	15.13	14.80	14.17	13.17	12.11	10.82	8.60
Methionine, g/day	3.96	4.34	4.54	4.57	4.56	4.46	4.27	3.96	3.63	3.24	2.81
Methionin+cystine, g/day [1,]	7.83	8.60	9.00	9.08	9.07	8.88	8.51	7.92	7.30	6.54	5.71
Cystine, g/day	3.87	4.25	4.46	4.51	4.50	4.42	4.25	3.96	3.67	3.30	2.90
Tryptophan, g/day	2.35	2.59	2.71	2.74	2.74	2.69	2.59	2.42	2.24	2.02	1.78
Threonine, g/day	8.42	9.26	9.70	9.80	9.79	9.59	9.21	8.59	7.94	7.13	6.25
Phenylalanine, g/day	6.49	7.14	7.50	7.58	7.58	7.45	7.17	6.71	6.22	5.62	4.96
Phenylalanine+tyrosine, g/day [1]	12.38	13.62	14.28	14.43	14.42	14.15	13.60	12.70	11.75	10.57	9.29
Tyrosine, g/day	5.90	6.48	6.79	6.85	6.84	6.70	6.43	5.99	5.52	4.95	4.33
Leucine, g/day	13.05	14.34	15.03	15.17	15.16	14.87	14.28	13.32	12.31	11.07	9.71
Isoleucine, g/day	7.14	7.84	8.22	8.29	8.28	8.12	7.79	7.26	6.70	6.02	5.27
Valine, g/day	9.15	10.06	10.55	10.66	10.65	10.45	10.04	9.37	8.66	7.79	6.84
Histidine, g/day	4.16	4.57	4.79	4.84	4.84	4.75	4.56	4.26	3.94	3.55	3.12
Arginine, g/day	5.57	6.11	6.39	6.43	6.42	6.27	5.99	5.54	5.08	4.51	3.90

[1] Amino acids are taken together due to the possibility of interconversion.

TABLE 16 - PERIOD, DAILY FEED INTAKE, ENERGY AND DIGESTIBLE AMINO ACIDS GIVEN IN SIMULATED DIET BY INRAPORC® FOR BARROWS BETWEEN 22 AND 129 KG.

Variable	Live weight, kg			
	22-50	50-75	75-100	100-129
Period, days	00-32	32-58	58-85	85-120
Daily feed intake, kg				
Minimum	1.72	2.30	2.80	3.28
Maximum	2.29	2.80	3.30	3.87
Mean	1.99	2.55	3.05	3.58
Metabolizable energy, kcal	3267	3263	3267	3272
Digestible energy, kcal	3385	3375	3370	3365
Lysine, g/kg	8.17	7.72	6.26	4.67
Methionine, g/kg	2.42	2.30	1.88	1.40
Methionine+cystine, g/kg [1,]	4.90	4.64	3.78	2.83
Cystine, g/kg	2.48	2.34	1.90	1.43
Tryptophan, g/kg	1.54	1.45	1.20	0.93
Threonine, g/kg	5.60	5.30	4.30	3.30
Phenylalanine, g/kg	4.07	3.84	3.16	2.40
Phenylalanine+tyrosine, g/kg [1]	7.72	7.30	5.99	4.52
Tyrosine, g/kg	3.65	3.46	2.83	2.12
Leucine, g/kg	8.07	7.68	6.27	4.71
Isoleucine, g/kg	4.55	4.29	3.51	2.63
Valine, g/kg	5.89	5.58	4.60	3.44
Histidine, g/kg	2.60	2.47	2.03	1.54
Arginine, g/kg	3.40	3.20	2.59	1.93

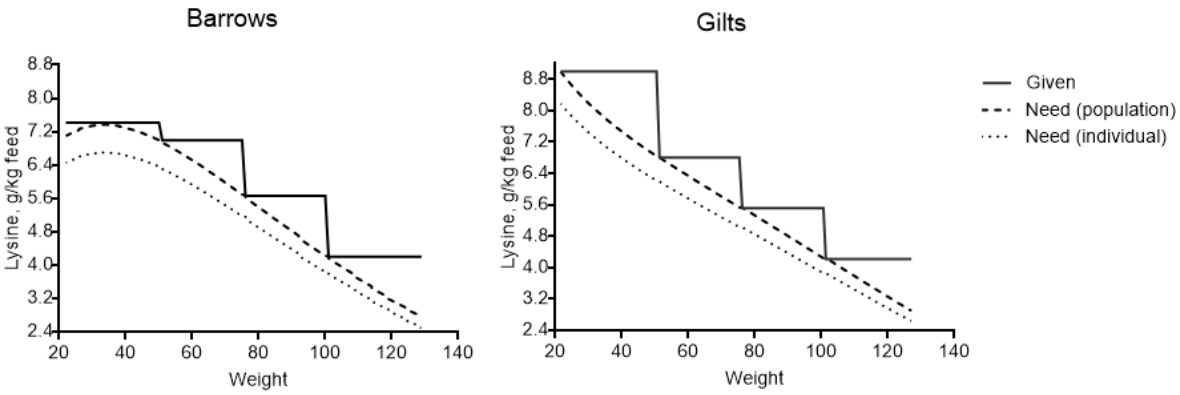
[1] Amino acids are taken together due to the possibility of interconversion.

TABLE 17 - PERIOD, DAILY FEED INTAKE, ENERGY AND DIGESTIBLE AMINO ACIDS GIVEN IN SIMULATED DIET BY INRAPORC® FOR GILTS BETWEEN 22 AND 127 KG.

Variable	Live weight, kg			
	22-50	50-75	75-100	100-130
Period, days	00-37	37-65	65-96	96-136
Daily feed intake, kg				
Minimum	1.25	2.21	2.62	2.83
Maximum	2.20	2.63	2.85	2.97
Mean	1.75	2.44	2.75	2.91
Metabolizable energy, kcal	3267	3263	3267	3272
Digestible energy, kcal	3385	3375	3370	3365
Lysine, g/kg	9.92	7.51	6.10	4.69
Methionine, g/kg	2.96	2.23	1.80	1.40
Methionine+cystine, g/kg [1,]	6.00	4.54	3.69	2.85
Cystine, g/kg	3.04	2.31	1.89	1.45
Tryptophan, g/kg	1.86	1.42	1.18	0.92
Threonine, g/kg	6.80	5.15	4.20	3.30
Phenylalanine, g/kg	4.91	3.79	3.07	2.40
Phenylalanine+tyrosine, g/kg [1]	9.35	7.17	5.83	4.53
Tyrosine, g/kg	4.44	3.38	2.76	2.13
Leucine, g/kg	9.83	7.48	6.12	4.75
Isoleucine, g/kg	5.53	4.19	3.44	2.68
Valine, g/kg	7.19	5.46	4.50	3.48
Histidine, g/kg	3.15	2.41	1.97	1.54
Arginine, g/kg	4.10	3.08	2.52	1.91

[1] Amino acids are taken together due to the possibility of interconversion.

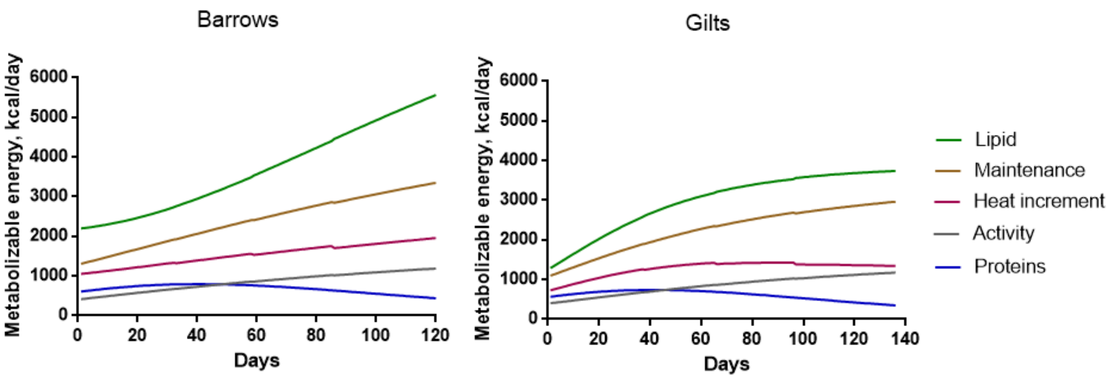
FIGURE 11 - DIGESTIBLE LYSINE GIVEN ACCORDING TO INRAPORC® SIMULATION, AND POPULATION AND INDIVIDUAL NEEDS FOR BARROWS AND GILTS BETWEEN 22 AND 129 KG.



As regards the evaluated crossbreed, the aim of using Moura and Duroc was to improve carcass and pork quality by increasing the amount of intra and extra-muscular fat. Intramuscular fat is associated with better sensorial characteristics, like softness (Teye et al., 2006) and juiciness (Fernandes et al., 1999a). Extramuscular fat increases water retention capacity (Candek-Potokar et al., 2002) and, when it comes to dry-cured production, lipolysis is responsible for the distinctive flavor of these products (Flores et al., 1997; Bolzoni et al., 1996). Fat deposition requires nearly seven times more energy than lean deposition (Lewis e Southern, 2001) and, when energy consumption exceeds the need for lean production, the excess energy is converted into fat (Whittemore, 1993). In this study, in order to maintain high levels of fat deposition, it was opted for keep high levels of energy on the diet.

INRAPORC® calculates the energy provided by a given diet and estimates energy use from each function (van Milgen et al., 2008). The partitioning of energy intake between lipid, maintenance, heat increment, activity and protein deposition are showed in Figure 12. In the simulated diet, the amount of energy used for protein deposition, activity and heat increment were similar for barrows and gilts. However, as barrows tended to have higher feed intake and higher weight gain, the amount of energy necessary for maintenance and the energy used for fat deposition were greater in barrows. The higher levels of fat accumulation in barrows is well known and broadly discussed in literature (Latorre et al., 2008; Peinado et al., 2008; Cisneros et al., 1996).

FIGURE 12 - PARTITIONING OF ENERGY INTAKE BETWEEN LIPID, MAINTENANCE, HEAT INCREMENT, ACTIVITY AND PROTEIN DEPOSITION IN BARROWS AND GILTS BETWEEN 22 AND 129 KG IN A DIET SIMULATED BY INRAPORC®.



3.4. Conclusions

The lysine need estimated by INRAPORC® increased until 70 kg in barrows and gilts: 16.30 and 15.13 g/day, respectively. As the INRAPORC uses the concept of ideal protein, the needs of other amino acids increased until this weight range.

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CHAPTER 4 – FINAL CONSIDERATIONS

The high levels of intramuscular and subcutaneous fat in the evaluated hybrid, mainly with 130 kg of live weight, showed that this hybrid may be used when the goal is to produce pork intended for high quality, with high levels of fat, and little effect in other qualities of meat. Although not evaluated in this study, the high levels of fat may contribute to a dry-cured or fermented production, which should be the aim of upcoming studies.

This study also showed that INRAPORC® is an effective tool to adjust amino acid levels of diets in some specific situations, and its use may reduce the production costs as well as reduce the nutrients released in the environment.

As meaningful as the observed results, the use of a Brazilian native breed should be highlighted. After the 70s, the pig production started to aim lean and native Brazilian breeds, such as Moura, and then were replaced by foreign breeds specialized in lean production. In this process, Moura got in danger of extinction, so only the Brazilian Research Corporation and few local producers kept the breed.

The study of this breed, when used in crosses or pure, represents a way of preserving the local genetic material and the biodiversity, produce more resistant pigs adapted to local conditions and maintain biodiversity and sustainable agricultural production. In this context, the author hopes that this thesis is useful to discuss the importance using Brazilian native pig breeds as a way of preserving the Brazilian culture, history and biodiversity.

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